Flood Plain Management Services

Rhode Island Stormwater Management Practices Study

April 1992

US Army Corps of Engineers
New England Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
April 1992

3. REPORT TYPE AND DATES COVERED
Flood Plain Management Services

4. TITLE AND SUBTITLE
Rhode Island Stormwater Management Practices Study

5. FUNDING NUMBERS

6. AUTHOR(S)
U.S. Army Corps of Engineers
New England Division

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, New England Division
424 Trapelo Road
Waltham, MA 02254-9149

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
conducted under the Corps of Engineers' Flood Plain Management Services (FPMS) Program, requested by the Rhode Island Department of Administration, Division of Planning, under Sect. 206 Flood Control Act, 1960 (PL 86-645)

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release
Distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The purpose of this study is to produce a technical document to help communities develop and incorporate proper stormwater management practices. This document deals primarily with flooding and drainage issues relating to stormwater management, but also discusses the relationship of stormwater management to water quality degradation and erosion and sedimentation. Two activities which promote the increase and degradation of stormwater runoff within a watershed are urbanization and agriculture. Urbanization creates an increase in the amount of impervious area reducing the infiltrative capacity of the site, which contributes to excess runoff and degenerated water quality flowing from the site. The process of agriculture such as clearing, grading, plowing, and the presence of livestock operations can significantly alter the soil structure resulting in an increase in runoff and a decrease in water quality. Various stormwater management techniques incorporated throughout a particular community may not be appropriate for a neighboring community due to hydrologic, geologic, social, and political differences.

14. SUBJECT TERMS
storm water, urban runoff, infiltration, water quality, sedimentation, erosion

15. NUMBER OF PAGES
90

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

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RHODE ISLAND STORMWATER
MANAGEMENT PRACTICES STUDY

April 1992
New England Division
Army Corps of Engineers

PREFACE

RHODE ISLAND STORMWATER MANAGEMENT PRACTICES STUDY

This study has been conducted under the Corps of Engineers' Flood Plain Management Services (FPMS) program at the request of the Rhode Island Department of Administration, Division of Planning. The purpose of this study is to produce a technical document to help communities develop and incorporate proper stormwater management practices. This document deals primarily with flooding and drainage issues relating to stormwater management, but also discusses the relationship of stormwater management to water quality degradation and erosion and sedimentation.

The volume and quality of stormwater runoff is dependent on the capability of the local soil type to provide infiltration capacity, geologic conditions (bedrock), local groundwater conditions, and the type and extent of vegetative cover at the site. These factors influence the characteristics and behavior of stormwater between the pre-development and post-development phases at a specific site.

The two basic activities which promote the increase and degradation of stormwater runoff within a watershed are urbanization and agriculture. Urbanization includes grading and clearing of a site for urban development which creates a more uniform surface deficient in natural storage capacity, and an increase in the amount of impervious area reducing the infiltrative capacity of the site. These factors contribute to excess runoff and degenerated water quality flowing from the site. Land cultivation and alterations such as clearing, grading, plowing, and the presence of livestock operations can significantly alter the soil structure resulting in an increase in runoff and a decrease in water quality.

The net effects of stormwater runoff due to urbanization or agricultural activities of a previously undeveloped site include:

- Increased peak discharges and volume of storm runoff.
- Decreased time needed for runoff to reach a stream.
- Increased frequency and severity of flooding.
- Reduced streamflow during prolonged periods of dry weather due to the reduced level of infiltration to recharge the watershed.
- Greater runoff velocity during storms.

These net effects are associated with three primary issues which can be addressed through the application of proper stormwater management practices. The three primary issues are:

1) Flooding and Drainage
2) Erosion and Sedimentation

and, 3) Water Quality

Stormwater management is the process by which a government or private entity determines the proper practices which will enable them to effectively and safely control the adverse impacts of stormwater runoff. Stormwater management should include efforts to control the magnitude and frequency of floods, the nature and severity of water pollution, and the significance of erosion and sedimentation problems.

Various stormwater control methods are presently available for addressing these issues. These methods can be categorized under one or more of the following four stormwater control strategies.

1. Regulatory and Institutional Controls

Regulatory and institutional controls include methods for developing a comprehensive stormwater management program at the state and local level.

2. Source Controls

Source controls emphasize the prevention and reduction of non-point source pollution and excess runoff before it reaches a stormwater collection system or receiving water.

3. Infiltration Methods

Infiltration practices are effective at providing storage capacity for excess runoff and at removing certain pollutants by filtering them through the surrounding soil. They require being situated in areas where the local soil and groundwater conditions are suitable for infiltration. The use of infiltration devices is very site-specific and should include careful consideration during the planning stages of any project.

4. Storage Methods

Storage facilities are a common method for controlling excess stormwater runoff. However, they are not generally used for water quality enhancement, unless designed as part of an overall system that includes stormwater treatment to remove pollutants.

The Rhode Island Department of Environmental Management (RIDEM) is significantly involved with the stormwater management process. The former Land Management Project maintained an inventory of Best Management Practices within Rhode Island which includes locations, descriptions, and annotations of Best Management Practices. They also issued a series of fact sheets describing various Best Management Practices. The fact sheets and other pertinent information concerning stormwater management can be obtained from the Rhode Island Department of Environmental Management's nonpoint source program.

The Department of Environmental Management's assessment of nonpoint source pollution sources notes that urban runoff, construction activity, road sanding and salting, and agricultural runoff are impacting waters throughout Rhode Island. In response to stormwater management problems, RIDEM is developing a stormwater program to improve flood control and water quality. The stormwater management plan includes applicability criteria, performance standards, and a forthcoming RIDEM Stormwater Design and Installation Manual. RIDEM also recommends that a model stormwater ordinance be developed and adopted by all communities through the legislative process. This will authorize local governments to require stormwater management controls for all new developments.

Various stormwater control practices may be used as part of an overall Stormwater Management program by local communities. Many types of stormwater management practices exist throughout Rhode Island and a few examples are described within the main report. However, the suitability of each particular practice must be determined on a site specific basis.

A successful Stormwater Management program must be based on a comprehensive approach which assures that the volume, peak discharge rate, and pollutant load leaving a site are no greater in the post-development phase than they were in the pre-development phase. Such a plan provides a means of assigning responsibility for design, construction and maintenance of stormwater control facilities, determining regulations for future land use and development within the watershed, and providing for the preservation and enhancement of water quality in the receiving waters.

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RHODE ISLAND STORMWATER
MANAGEMENT PRACTICES STUDY

I. INTRODUCTION

Study Authority

This study has been conducted under the Corps of Engineers' Flood Plain Management Services (FPMS) program and at the request of the Rhode Island Department of Administration, Division of Planning. The FPMS program is authorized under Section 206 of the Flood Control Act of 1960 (PL 86-645). This program allows the Corps to provide planning and technical assistance to states relating to flooding and flood plain management.

Study Purpose

The purpose of this study is to produce a technical document to review existing information on stormwater management practices and suggest ways to help Rhode Island communities develop and incorporate proper stormwater management practices. This document deals primarily with flooding and drainage issues relating to stormwater management, but also discusses the relationship of stormwater management to water quality degradation and erosion and sedimentation.

There are numerous factors involved with planning and designing a stormwater management facility. It should be emphasized that each stormwater management facility is unique and site-specific and should be carefully planned, designed, constructed, and maintained in a manner consistent with both local policies and those policies which pertain to the watershed in which it is located. Various stormwater management techniques incorporated throughout a particular community may not be appropriate for a neighboring community due to hydrologic, geologic, social, and political differences. For example, stormwater management techniques designed for a community with well drained soils and a low water table may not be suitable for communities with mostly clay soils or with bedrock relatively close to the surface.

Neighboring communities' stormwater management goals may differ from each other even if located within a common watershed. Certain communities may be particularly interested in recharging groundwater aquifers, or preventing flooding, while others may be concerned primarily with the quality of receiving waters. Coastal communities must make sure that bylaws and regulations exist to control runoff not only into streams and rivers, but also into coastal waters (harbors, coves, lagoons, etc.) and that stormwater management facilities are not improperly situated in areas frequently inundated by storm surge and waves.

There are many factors involved with choosing the stormwater management techniques most suitable for your community. This document attempts to define the stormwater management problem, and present and briefly describe some of the more common methods currently available.

II. WHAT IS STORMWATER RUNOFF AND HOW DOES IT AFFECT YOUR COMMUNITY?

Stormwater runoff generated by rainfall is equal to the total amount of rainfall over a specific drainage area less infiltration, transpiration, evaporation, and surface storage. The volume and quality of runoff is dependent on the capabilities of the local soil type to provide infiltration capacity, geologic conditions (bedrock), local groundwater conditions, and the type and extent of vegetative covering at the site.

Stormwater is capable of creating flooding of developed sites and local streams, erosion of soil and ground cover, sedimentation of waterways, and degraded water quality in a community.

The two basic activities which promote the increase of stormwater runoff within a watershed are urbanization and agriculture.

1. Urbanization

   Grading and clearing of a site for urban development creates a more uniform surface deficient in natural storage capacity. An increase in the amount of impervious area reduces the infiltrative capacity of the site. These factors contribute to excess runoff and degenerated water quality flowing from the site.

2. Agriculture

   Land cultivation and alterations such as clearing, grading, and plowing, and the presence of livestock operations can significantly alter the soil structure resulting in an increase in runoff and a decrease in water quality.

For example, increased runoff volume and velocity due to larger amounts of impervious surfaces at developed sites increases the potential for erosion and contributes to increased amounts of pollutant transport from the site to the receiving waters. However, the presence of vegetative cover can provide temporary storage of rainfall on plant and tree surfaces, help stabilize the soil decreasing the potential for erosion, and provide natural filtering of pollutants for enhanced water quality.

According to "Controlling Urban Runoff: A Practical Manual for Planning & Designing Urban BMP's" (Reference 15), when development occurs at a site, the net effects on stormwater runoff include:

- Increased peak discharges.
- Increased volume of storm runoff.
- Decreased time of concentration. This is the time needed for runoff to reach a stream.

- Increased frequency and severity of flooding.

- Reduced streamflow during prolonged periods of dry weather due to the reduced level of infiltration to recharge the watershed.

- Greater runoff velocity during storms due to higher peak discharges, rapid time of concentration, and smoother hydraulic surfaces.

All of the effects listed above are associated with three primary issues which can be addressed through the application of proper stormwater management practices. These three issues are:

1) Flooding and Drainage

2) Erosion and Sedimentation

and, 3) Water Quality

<u>Flooding and Drainage</u>

When a previously undeveloped site undergoes development, changes occur to the site which induce increased stormwater volumes and peak discharges. There is more impervious surface area which prevents runoff from infiltrating into the soil. Removing vegetative cover and grading the natural depression areas of a site also increases stormwater runoff and the time it takes to reach the receiving waters. If development occurs at numerous sites within a watershed, there can be significant adverse impacts on the watershed's hydrology. These impacts include:

- Flooding of the watershed's streams.

- The elevation of the stream's floodplain to accommodate post-development discharge rates. This means that property and structures not previously in the floodplain may now be at risk due to post-development runoff volumes.

- Less water available for infiltration to the watershed due to impervious areas preventing local groundwater recharge.

<u>Erosion and Sedimentation</u>

Increased runoff velocities and volumes can lead to alterations in the natural geometry of streams and create surface erosion problems on site. Post-development stormwater runoff flows lead to greater stream flows and streambank erosion. Banks may be undercut and slump into the channel creating sedimentation and compounding flooding problems. Sediment from areas such as construction sites with uncontrolled runoff, and sand applied to roadways as deicing agents may also be deposited in stream channels causing flooding problems. These sediments may also be carrying pollutants from the site creating water quality problems. Methods for controlling erosion and sedimentation are available from the Rhode Island Department of Environmental Management and contained in the Rhode Island Soil Erosion and Sediment Control Handbook.

Water Quality

Non-point source pollution is created when stormwater dislodges, dissolves, and transports pollutants to receiving waters. Stormwater runoff from developed sites may carry numerous pollutants generated from roads, parking lots, roof drains, junk yards, and other storage areas. The accumulated residue and debris in the runoff from these areas is transported overland, eventually entering streams, lakes or groundwater. Suspended solids, heavy metals, nitrates and hydrocarbons are just some of the pollutants which have been identified in urban runoff. Fertilizers, pesticides, and animal wastes are other sources of pollution, especially in agricultural areas. Stormwater pollutant loads at the beginning of a storm are significantly higher than during the latter part of the storm. Ninety percent of the pollutant load is carried in the first one inch of runoff due to rainfall. This is known as the "first-flush" effect. Treatment and control of runoff generated during the first-flush can be addressed by using Best Management Practices described in Part IV of this report.

III. WHAT IS STORMWATER MANAGEMENT?

Stormwater Management is the process by which a government or private entity determines the proper practices or methods which will enable them to effectively and safely control the adverse impacts of stormwater runoff associated with urban and agricultural development.

Until recently, stormwater management was concerned only with the flooding and drainage issues of stormwater runoff. Stormwater management systems were previously designed without consideration to the other issues pertaining to stormwater problems such as erosion, sedimentation, and water quality. Therefore, stormwater management should include not only efforts to control the magnitude and frequency of floods, but also the nature and severity of water pollution, and the significance of erosion and sedimentation problems. The importance of water quality of runoff has increased in recent years. As an example, regulations issued by the U.S. Environmental Protection Agency require a National Pollutant Discharge Elimination System permit for stormwater system discharges. At present, only cities with a population over 100,000 are required to submit permit applications. However, certain small municipal separate storm sewer systems serving less than 100,000 people may be required to obtain a permit if their system is interconnected with a previously designated system. At present, Providence is the only municipality in Rhode Island required to obtain a permit under these guidelines. Currently, there are no plans to require other municipalities within Rhode Island to obtain a permit for stormwater system discharges.

A successful Stormwater Management program must be based on a comprehensive approach which assures that the volume, peak discharge rate, and pollutant load leaving a site are no greater in the post-development phase than they were in the pre-development phase. Such a plan provides a means of assigning responsibility for design, construction and maintenance of stormwater control facilities, determining regulations for future land use and development within the watershed, and providing for the preservation and enhancement of water quality in the receiving waters. A comprehensive Stormwater Management program should address:

- Goals - Specific goals related to the detrimental hydrologic effects of development.
- Design Criteria - Design and construction criteria for stormwater management facilities.
- Inspection - Periodic inspections of completed facilities.
- Maintenance - Periodic maintenance of these facilities.

Stormwater Management Program Goals

Primary goals of an effective local Stormwater Management program should include:

- The efficient removal of stormwater from flood prone or threatened areas, and the preservation of existing streamflow conditions.

- Control of erosion and sedimentation problems.
- Protection of water supplies from runoff pollutants.

These goals can be accomplished through the implementation of a comprehensive Stormwater Management program which should include the following key elements: (Reference 2)

- Specific legislation authorizing local governments to enact stormwater management regulations.
- An explanation of the goals and objectives of the program.
- Cooperation with neighboring local governments who may share the same watershed.
- A permit and plan review process for all new developments.
- Watershed or multi-site stormwater controls as an alternative to on-site facilities.
- Design criteria used to review specific Stormwater Management plans. This should include a complete list of acceptable stormwater control methods and maintenance considerations.

Stormwater Management Design Criteria

A comprehensive Stormwater Management program must include specific criteria for the design and construction of stormwater management facilities.

A set of design criteria is a very important component of a Stormwater Management program. It is used by government agencies in reviewing plans submitted by developers and by engineers designing the particular stormwater facility for that site. Recommendations for design guidelines for various flood and water quality control measures can be found in "Recommendations of the Stormwater Management and Erosion Control Committee Regarding the Development and Implementation of Technical Guidelines for Stormwater Management" (RIDEM - June 1988), Reference 14.

Construction criteria such as the work sequence, techniques, and future maintenance considerations for various stormwater management methods should also be developed. "Serious maintenance problems can be averted, or in large part mitigated, by the adoption of relatively simple measures during construction." (Reference 9)

Stormwater Management Facilities Inspection

The inspection of stormwater management facilities during and after construction is an integral part of a comprehensive Stormwater Management program. This is to ensure that the facility is constructed according to the approved plans and to ensure proper maintenance is being accomplished at the site. Inspections should be carried out by both the government agency regulating the Stormwater Management program, and more frequently by the owner/operator of the facility.

Stormwater Management Facilities Maintenance

Maintenance will ensure the proper functioning of the stormwater management facility. Failure to provide proper maintenance will reduce the hydraulic capacity and pollutant removal efficiency of the system. Responsibility for maintenance of a facility, both financial and administrative, should be clearly defined by local stormwater management regulations. A maintenance schedule should be developed for the life of the facility along with minimum criteria for frequency of maintenance. Proper maintenance of a site includes care for vegetation, debris and sedimentation removal, and repair and replacement of defective parts to ensure proper functioning of the stormwater management system.

Maintenance requirements are provided in the following sections for most of the stormwater management facilities described.

IV. WHAT METHODS OF STORMWATER MANAGEMENT ARE PRESENTLY AVAILABLE?

There are numerous stormwater control methods which are presently available. For purposes of this study, each stormwater control method has been placed under one or more of the following four stormwater control strategies. (Reference 11)

1. Regulatory and Institutional Controls
2. Source Controls
3. Infiltration Methods
4. Storage Methods

These four strategies, and examples, are discussed in the following section. Each section describes various stormwater control practices which may be used as part of an overall Stormwater Management program by local communities. The suitability of each particular practice must be determined on a site specific basis. These sections provide a brief description of each method and which stormwater issues they are best suited to resolve. As previously stated, the three primary issues addressed by stormwater management are:

1. Flooding and Drainage	FD
2. Erosion and Sedimentation	ES
3. Water Quality	WQ

Tables are provided at the end of each section summarizing key points of various stormwater management practices and which issues these practices are capable of resolving. Many issues cannot be resolved by a single method but require a complete and comprehensive stormwater management program.

Regulatory and Institutional Controls

Regulatory and institutional controls include methods for developing a comprehensive stormwater management program at the local level. Instituting a stormwater ordinance to regulate the quantity and quality of runoff is one such method.

1. Zoning Ordinances/Regulations

Zoning ordinances and land use regulations pertaining to the control of stormwater runoff are an effective method toward averting future problems with flooding, downstream erosion, and water quality associated with constructing new developments. These ordinances and regulations should be part of a comprehensive stormwater management program of a community.

Local zoning ordinances and land use regulations can be effective tools in preventing development from occurring in sensitive or critical areas of a watershed.

A recent report issued by the Rhode Island Department of Environmental Management (RIDEM), "Stormwater Runoff: Problems And Recommendations For Rhode Island" (Reference 1), has recommended that a model stormwater management ordinance be developed and adopted by all communities. This will authorize local governments to require stormwater management controls for all new developments within their jurisdiction.

Rhode Island has a new general zoning enabling act (Chapter 45-24 of the General Laws) which requires that municipal ordinances address "appropriate drainage requirements and methods to manage stormwater runoff," in Section 33-(4)-(H).

Sample bylaws and regulations pertaining to stormwater runoff are given in "Sample Bylaws and Regulations: Southeastern Regional Planning and Economic Development District" (Reference 16). The objective of the sample drainage regulation is to maintain pre-development levels of stormwater runoff rates and volumes. The sample drainage regulations can be adopted as basic principles which supplement technical specifications in subdivision regulations. The regulations are also used to establish performance standards, and to protect the water quality of receiving streams.

Some municipal ordinances require detention basins to control stormwater, but may also allow other measures such as rooftop storage, infiltration trenches, or porous pavement if continued maintenance is feasible. Nonstructural management practices such as clustering land uses into the least vulnerable sites, preservation of open space, and protection of wetlands are also encouraged.

The former Land Management Project was an organization jointly funded by the Rhode Island Department of Environmental Management (RIDEM) and the U.S. Environmental Protection Agency. They assisted communities in evaluating the impacts of their land use decisions on stormwater management problems, specifically the quality of wetlands, ponds, estuaries, and groundwater. The Land Management Project also maintained an inventory of local ordinances which contained a listing of sample and model ordinances which pertain to water quality, stormwater, and soil erosion and sedimentation.

However, the Land Management Project is no longer in existance, but written materials are available through the Rhode Island Department of Environmental Management's nonpoint source program. Some of this material includes fact sheets pertaining to subdivision regulations, zoning, and site plan review. These fact sheets are shown in Appendix C.

2. Stormwater Utility

Stormwater utilities provide a means of adequately maintaining stormwater runoff facilities by collecting fees from users of the stormwater system. A primary advantage of the stormwater utility is the creation of a new revenue source devoted to supporting the local stormwater management program. The fees are also available for capital improvements to the system. The justification for a utility approach to stormwater management is typically stated in terms of contribution to the problem. In this case, "users" are defined as properties that add runoff to the system. Fee structures are based on some measure of the amount of runoff generated from a property.

A stormwater utility has the potential to generate a steady cash flow for capital improvements and maintenance, provide an equitable method of revenue collection with structured user fees, and create an entity which has the ability to borrow funds for needed improvements to the system.

Stormwater utilities are essentially a means of financing the maintenance and capital improvements to a stormwater management system. They are a not a stormwater management program in themselves, but only a part of a comprehensive program which includes zoning ordinances, design criteria, and other specific guidance on stormwater management for a particular watershed. However, stormwater utilities may not be suitable for or effective in rural areas where development activities are limited in scope and involve only a small portion of the total watershed area. The following states are known to have communities with stormwater utilities: Washington, Oregon, Colorado, Maryland, Florida, and Ohio.

3. Coordination/Cooperation

Stormwater runoff is not limited by the jurisdictions of various municipal boundaries. Therefore, neighboring governments of a watershed must cooperate to avoid the adverse impacts of development.

One example for the need for coordination and cooperation is the use of detention ponds. Detention ponds in a particular community may solve localized stormwater runoff problems, but their use in the lower portions of a watershed may actually exacerbate downstream flooding. Detention ponds are capable of reducing the peak flow, but create relatively high flows which persist for extended periods of time. Reference 13 outlines this problem and shows that detention basins situated in the lower portions of a watershed are capable of causing extended periods of relatively high discharge. This extended period of high discharge from the detention basin combined with the natural high flows from upstream portions of the watershed create a peak flow which may actually exceed the level originally experienced without the use of a detention basin. This example shows that coordination and cooperation among local governments and agencies within a watershed are essential elements of a comprehensive stormwater management program.

Other forms of stormwater management are valid with or without intermunicipal coordination. These include techniques such as swales, filter strips, and dry wells which are suitable for relatively small, individual residential or commercial lots.

Coordination and cooperation among communities within the same watershed are essential components of a comprehensive stormwater management program.

SUMMARY OF REGULATORY
AND INSTITUTIONAL CONTROLS

Practice/Key Points	FD	ES	WQ	Reference
1. Zoning Ordinances/ Regulations o Prevent undesirable development in sensitive areas. o Local governments have authority to regulate land use within a watershed and require the use of proper storm-water management techniques.	●	●	●	1,4,11,16
2. Stormwater Utility o Generate revenue for maintenance and capital improvements to stormwater system. o Based on "user" fees. Users are defined as properties that add runoff to the system.	●	●	●	6
3. Coordination/Cooperation o Cooperation among local governments within a watershed is essential to resolving stormwater problems caused by developments. o Coordination with neighboring towns, municipalities, and agencies is essential toward developing a comprehensive stormwater management program.	●	●	●	2,7,8,17

Source Controls

Source controls emphasize the prevention and reduction of non-point source pollution and excess runoff before it reaches a stormwater collection system or receiving water. Source control activities include:

1. Solid Waste Management

Street litter, including glass, paper, and metals can end up in stormwater discharges. This results in visible floating pollution of the receiving waters. Recycling programs established in many communities have alleviated this problem.

2. Street Sweeping

While street sweeping itself is not an effective method of stormwater management, it does help prevent debris and sediment from entering the storm drains and receiving waters. This can ultimately reduce maintenance costs of a storm drainage system by requiring less frequent sediment and debris removal.

3. Catchbasin Cleaning

Regular maintenance and cleaning of catchbasins can remove accumulated sediment which could discharge to receiving waters. This maintenance activity reduces costs of sediment and debris removal from stormwater management facilities.

4. Soil Erosion Control

Maintaining vegetative cover and barriers at construction sites is an effective method of reducing soil erosion. A dense grass covering at infiltration devices such as trenches and swales is essential for maintaining the overall integrity of the stormwater management facility. Soil erosion control is also necessary at other infiltration devices such as porous pavement, which can be highly susceptible to clogging.

5. Deicing/Snow Removal

Limiting the use of chemicals and sand to the minimum amount necessary for deicing roads helps reduce the the amount which accumulates in catch basins and sensitive receiving waters. This can reduce and prevent maintenance costs of cleaning out catch basins. Infiltration devices are particularly susceptible to sediment accumulation and clogging. Abrasive materials used for snow and ice removal, such as sand, should not be used with porous pavement.

6. Fertilizer and Pesticide Control

Controlling the storage and use of chemicals on municipal lands will help reduce concentrations in the receiving waters. The use of pesticides and fertilizers by individual homeowners can also affect the local receiving water quality and the performance of certain stormwater management devices such as grassed swales, and vegetative filter strips which require proper care and maintenance of their vegetative covers.

SUMMARY OF SOURCE CONTROLS

Practice/Key Points	FD	ES	WQ	Reference
1. Solid Waste Management o Eliminates debris in receiving water.			●	11
2. Street Sweeping o Prevents debris/sediment from entering storm drains.			●	11
3. Catchbasin Cleaning o Prevents debris/sediment from entering receiving waters.			●	11
4. Soil Erosion Control o Reduces loss of soil by maintaining vegetative cover/barriers.		●	●	11
5. Deicing/Snow Removal o Helps reduce accumulation of sand and chemicals in collection system and receiving waters.			●	11
6. Fertilizer/Pesticide Control o Control storage and use of chemicals. to prevent them from entering receiving waters.			●	11

Infiltration Methods

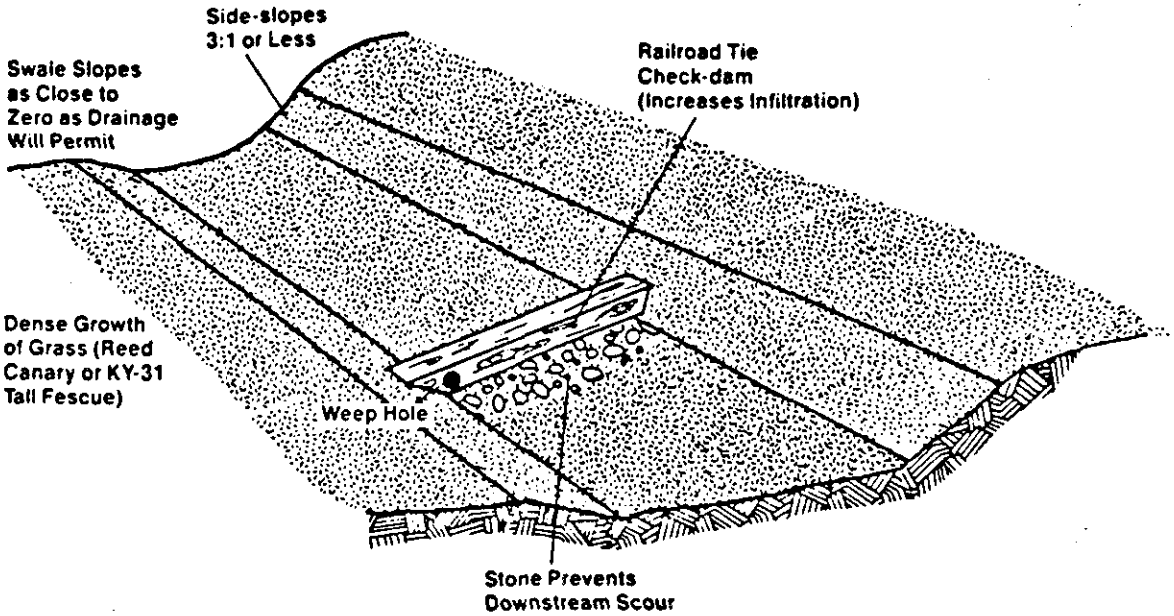
Infiltration practices are effective at providing storage capacity for excess runoff and at removing certain pollutants by filtering them through the surrounding soil. They are best suited for small watersheds that do not have concentrated, erosive flows or heavy sediment loads. They also require being situated in areas where the local soil and groundwater conditions are suitable for infiltration. The Rhode Island Stormwater Management and Erosion Control Committee in its June 1988 report does not recommend the extensive use of infiltration methods throughout Rhode Island. This is due to the susceptibility of infiltration devices to fail due to sediment accumulation, maintenance difficulties, and the potential for groundwater contamination. However, the committee does recommend the limited use of certain infiltration methods either independently or in conjunction with wet basins, when appropriate. The use of infiltration devices is very site-specific and should include careful consideration during the planning stages of any project.

Reference 15 is an excellent source of information on infiltration methods. It contains design, construction, and maintenance criteria, and provides guidance on construction and maintenance costs for each of the infiltration methods.

1. Vegetated or Grassed Swales

Swales are considered to be a Best Management Practice suitable for treating the "first-flush" effect. See Figure 1. The "first-flush" effect is the first half to one inch of runoff generated during a storm event. It carries up to 90% of the pollutant load from the total runoff. An infiltration Best Management Practice such as this is suitable only for areas with porous soils and where the water table is well below the surface. Swales are typically applied in single family residential areas of low to moderate density and where the percentage of impervious cover is relatively small. The vegetation cover provides a non-erosive flow velocity and an opportunity for some runoff pollutant removal through infiltration. Swales, when constructed with a check dam, provide control of peak discharges by reducing the runoff velocity and therefore the time of concentration, and by reducing the volume of runoff through infiltration. However, swales have a limited capacity to accept runoff from large storms. The vegetation cover provides a non-erosive flow velocity and an opportunity for some runoff pollutant removal through infiltration. It has been recommended that swales be used in combination with other methods to meet stormwater management requirements. A swale used to aid in controlling water quality is sometimes combined with a storm sewer for flood protection. A raised lip on the storm sewer inlet retains the "first-flush" one inch of runoff within the swale and allows the remaining stormwater to be conveyed to a suitable detention area for later release.

Maintenance of a swale involves periodic mowing, reseeding and weed control. The property owner, usually homeowners, are responsible for maintenance of a swale. The swale should be maintained with a dense grass cover. Excessive application of fertilizers and pesticides can be detrimental to a swale's performance.



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

SWALE

FIGURE 1

2. Retention Basin/Wet Pond

Retention basins are infiltration Best Management Practices used to keep the runoff on-site and allow it to infiltrate into the soil. See Figure 2. Retention facilities store the stormwater runoff which is gradually removed by infiltration and evaporation rather than being discharged to surface waters. They are designed to permanently store the volume of runoff generated by a given storm event at the site. Although they are an extremely effective method for controlling water quality and post-development peak discharge rates, they do not decrease the volume of runoff from the site. According to Reference 15, retention basins/wet ponds are most cost effective in larger, more intensely developed areas. They are most suitable in residential and commercial developments larger than twenty acres with a reliable source of water.

Wet weather inspections of these facilities should be conducted on an annual basis with funds reserved for routine maintenance (mowing, debris removal) and non-routine maintenance (regrading or reseeding of the entire facility). Retention basins/wet ponds can be an amenity in residential developments, especially where a homeowners association exists to ensure regular maintenance of the facility.

3. Porous Pavement

Porous pavement consists of a porous bituminous concrete paving material and a high void aggregate base that allows rapid infiltration and temporary storage of runoff. See Figure 3. It reduces the quantity of runoff generated on road surfaces, provides water quality enhancement of runoff through soil infiltration, recharges groundwater, and controls streambank erosion.

This practice is applicable to automobile parking areas and low-volume access roads in areas where groundwater table and soil conditions are suitable and where off-site runoff is not significant. The soil must be permeable and the site must have a relatively deep water table and bedrock to accept runoff from porous pavement. It is advisable that the underlying soils have a minimum infiltration rate between 0.27 and 0.52 inches/hour. The porous pavement is generally composed of four layers:

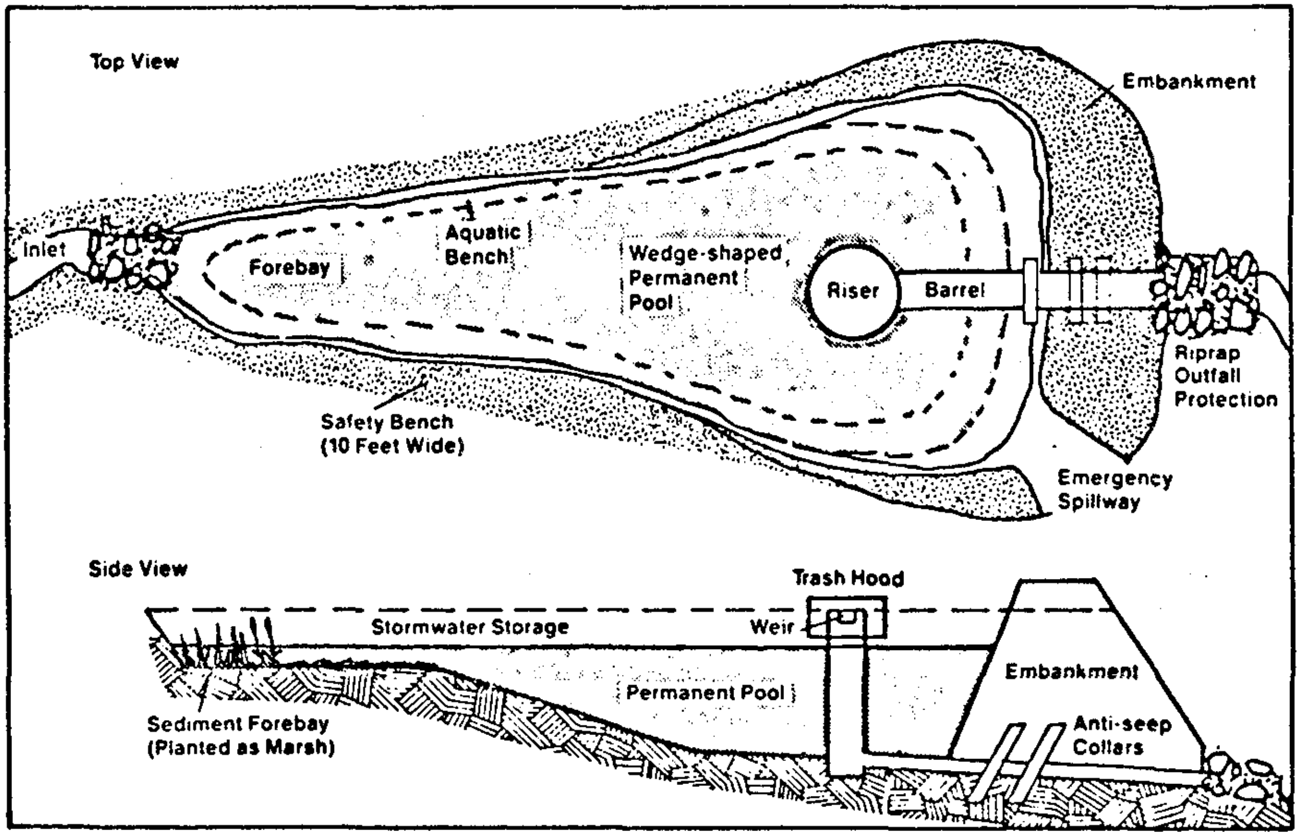
1. A minimally compacted subbase of undisturbed existing soil.

2. Reservoir base course consisting of 1-1/2 to 3 inch diameter stone.

3. Two inches of 1/2 inch aggregate to stabilize the reservoir base.

4. Porous asphalt paving surface.

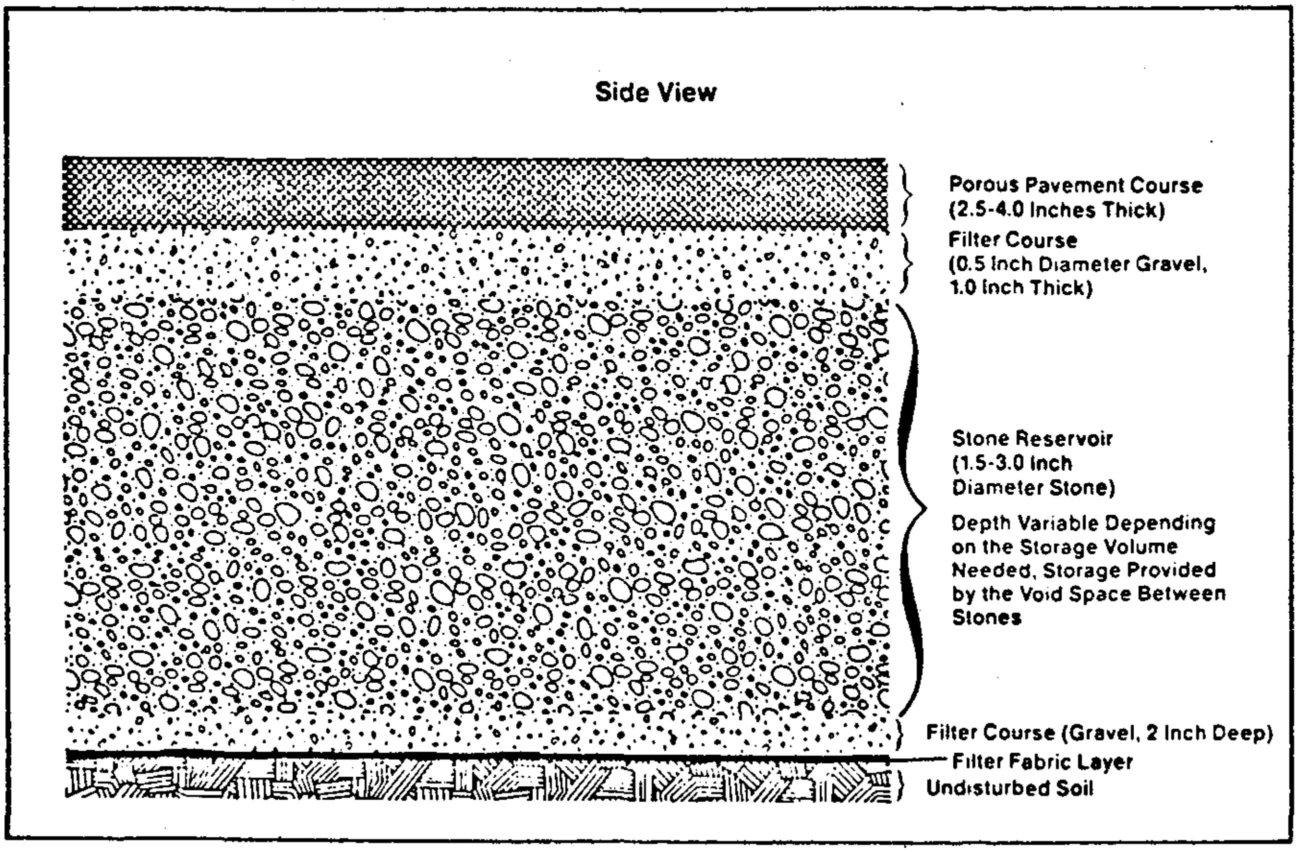
5. A layer of filter fabric (geotextile membrane) placed between the soil and reservoir base course.



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

RETENTION BASIN/WET POND

FIGURE 2



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

POROUS PAVEMENT

FIGURE 3

Porous pavement can be a cost effective Best Management Practice if properly maintained. Clogging of the pavement is common and must be controlled before, during and after construction. This can be accomplished through pretreatment of the runoff to remove sediment, grit, and oil by using sand filters, trenches, and oil separators. Maintenance requirements include vacuuming and hosing the pavement surface at least four times a year. This is an important maintenance activity which should be considered early in the planning stages of this method. Porous pavement sites are usually posted to warn against resurfacing with conventional pavement, using abrasives such as sand for snow removal, and parking heavy equipment on the surface.

4. Infiltration Trenches/Basins

Infiltration trenches are excavated trenches which have been backfilled with coarse stone aggregate material and are designed to provide temporary storage of runoff while it is released into the soil. See Figure 4. Infiltration trenches reduce on-site runoff volumes with few or none of the surface area requirements common to other stormwater management practices. They are suitable for small drainage areas of 1 acre or less.

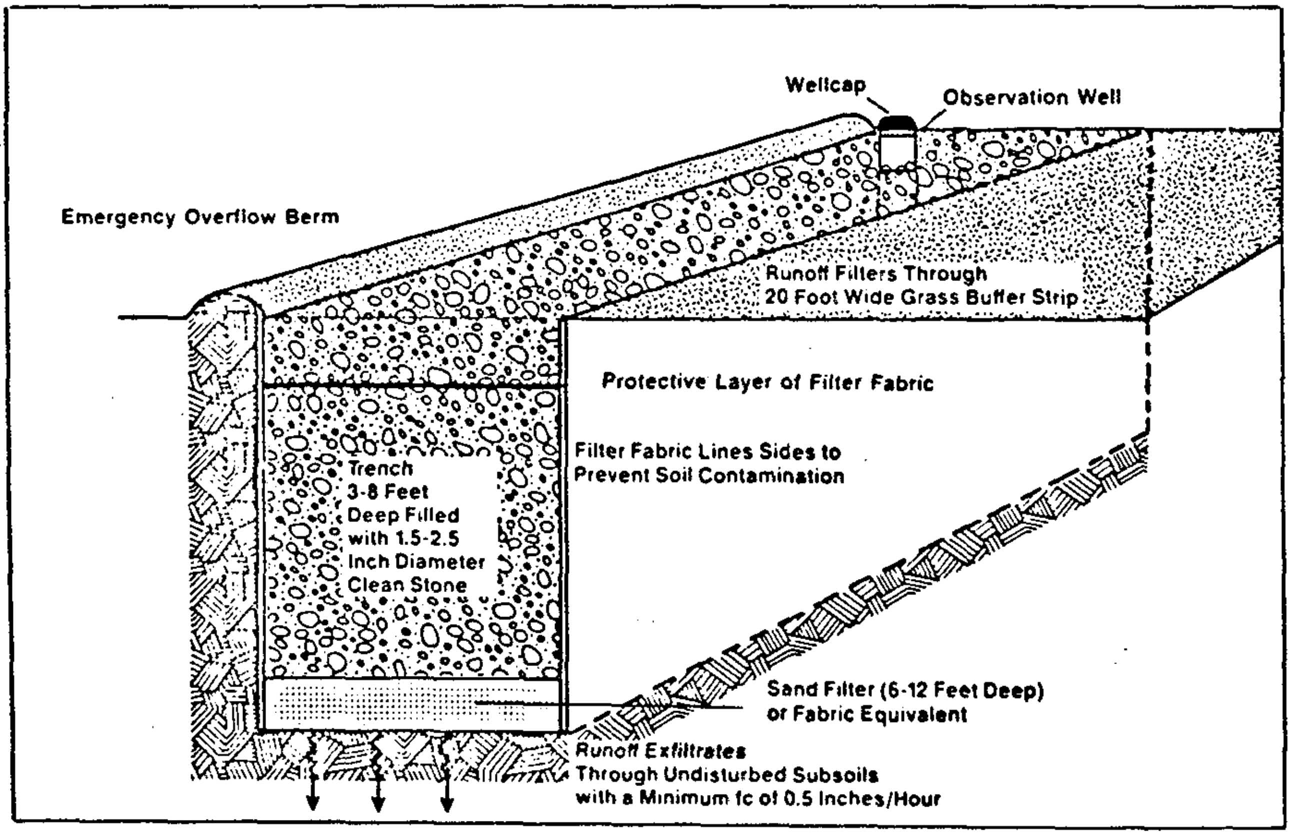
Unlike retention/detention basins, infiltration trenches can provide adequate runoff volume control for small and moderately sized storms. The infiltration of the storm runoff removes this volume of water from downstream areas providing streambank erosion control immediately downstream from the site. However, because infiltration trenches are usually applied to small sites, other practices should be installed within the watershed to provide comprehensive protection.

Infiltration basins are water impoundments created by dam or embankment construction in a permeable soil. See Figure 5. In general, they are capable of treating runoff from large drainage areas (5 - 50 acres) and typically require large surface areas.

Infiltration basins can completely manage peak discharge rates, provide groundwater recharge, reduce storm runoff volumes, and protect downstream channels from erosion. A combined infiltration/detention basin can completely attenuate peak discharges to the pre-development level.

Infiltration trenches and basins can effectively provide water quality control by removing soluble and particulate pollutants. They are also capable of attenuating peak discharge rates associated with large storms and, depending on the needs of a particular site, they can also provide groundwater recharge and streambank erosion control. Diverting runoff volume to the soil through the infiltration process also helps maintain headwaters of small streams during dry weather periods.

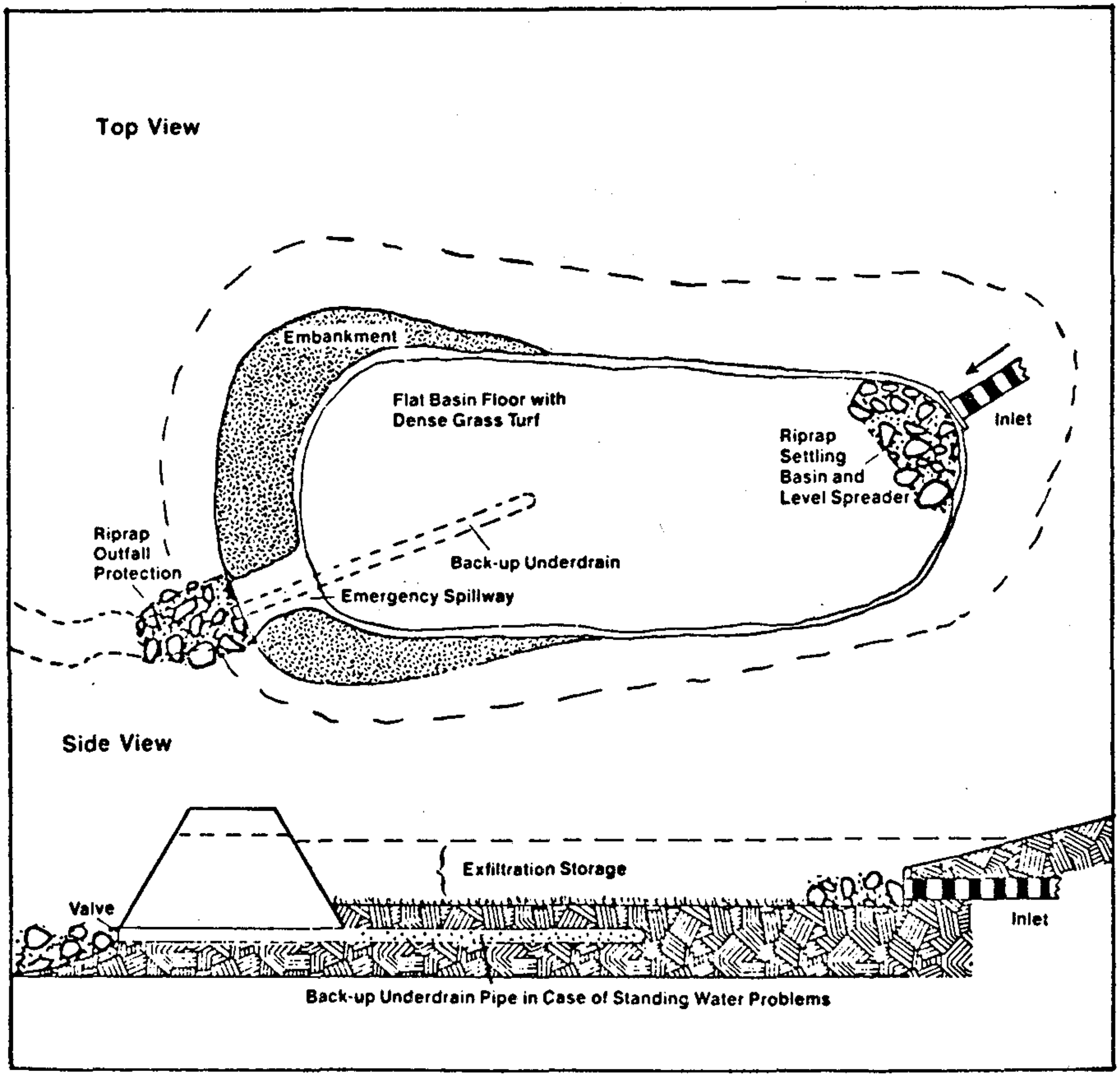
Reference 15 recommends that a maintenance agreement be included as part of the property deed for infiltration trenches. This should also include maintaining a dense grass buffer strip and removing accumulated sediments. Maintenance for these infiltration methods should also include annual wet-weather inspections. The infiltration basin floor should be



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

INFILTRATION TRENCH

FIGURE 4



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

INFILTRATION BASIN

FIGURE 5

mowed twice a year to prevent brush and tree growth. Standing water due to gradual surface clogging can be alleviated by deep tilling operations.

5. Vegetated Filter/Buffer Strips

Filter strips are similar to swales except that filter strips are designed only to handle sheet flow. See Figure 6. Sheet flow is runoff which flows in a thin, even layer over the surface. Runoff from impervious areas within the drainage area must be evenly distributed over the filter strip. Runoff flow that concentrates and channelizes will prevent the filter strip from performing as designed. Filter strips should be used to treat non-concentrated flows from residential areas, parking lots, and driveways.

Filter strips are only one component of a comprehensive stormwater management program. They do not provide sufficient storage capacity or effectively reduce peak discharge rates. However, they are capable of slightly reducing both runoff volume and runoff velocity. They can be used to reduce costs and sizes of downstream control methods.

Some common uses for filter/buffer strips include (Reference 9):

- o Surrounding infiltration structures such as retention basins/wet ponds to aid in reducing sediment loads.
- o Adjacent to watercourses.
- o Along the tops and toes of slopes.
- o At the outlets of other stormwater management structures.

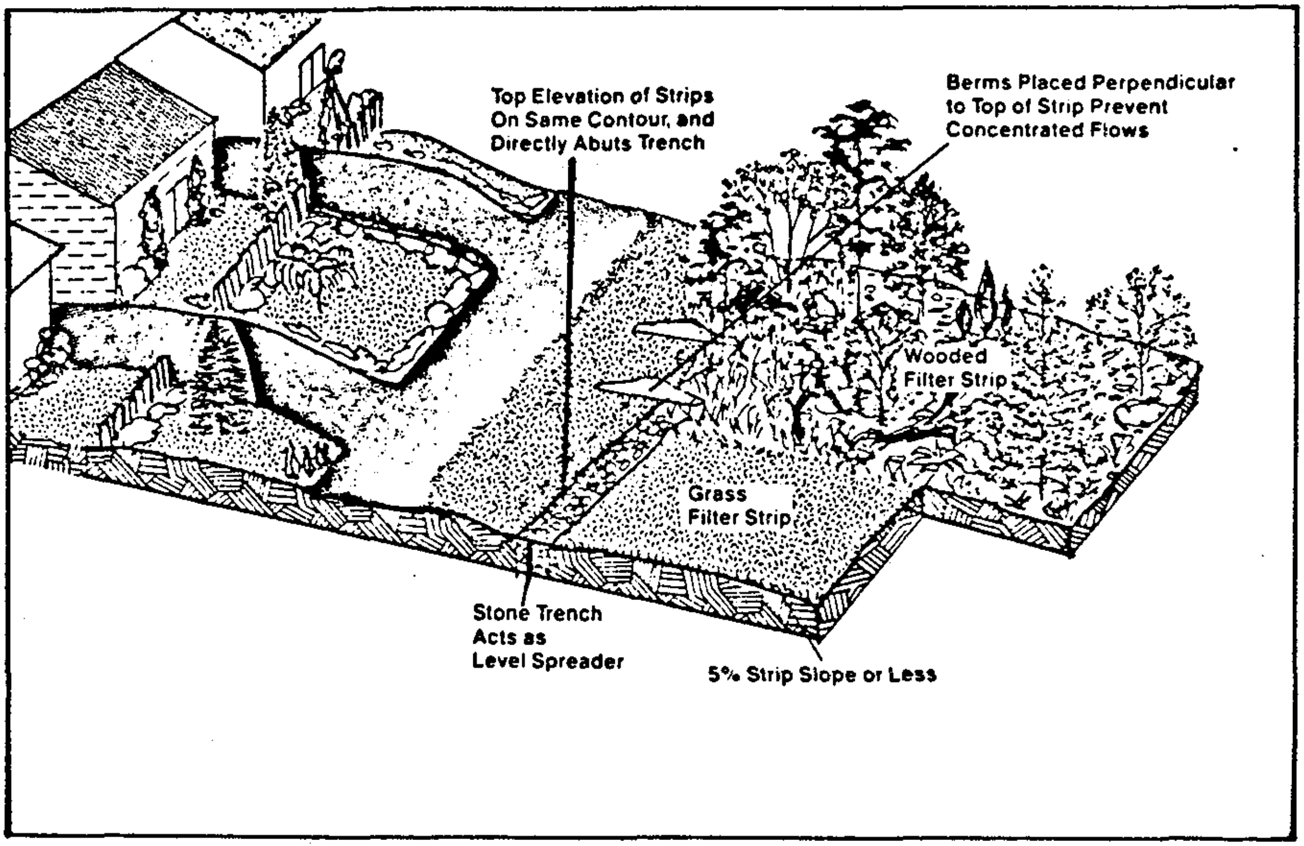
Maintenance of filter/buffer strips includes routine maintenance such as mowing and care of the vegetative cover.

6. Dry wells

Dry wells are similar to infiltration trenches, but are usually smaller. See Figure 7. Dry wells are an effective on-site solution for reducing runoff volumes from rooftops and driveways at sites less than one acre. They capture and store runoff and provide a means of infiltration for the stormwater. When used in conjunction with other stormwater management methods, dry wells reduce the volume requirements of detention basins and also may contribute to a reduction in the transport of pollutants. Sediment control around dry wells is required to prevent buildup and clogging. Maintenance of dry wells includes sediment and debris removal on a regular basis.

7. Wetlands Systems

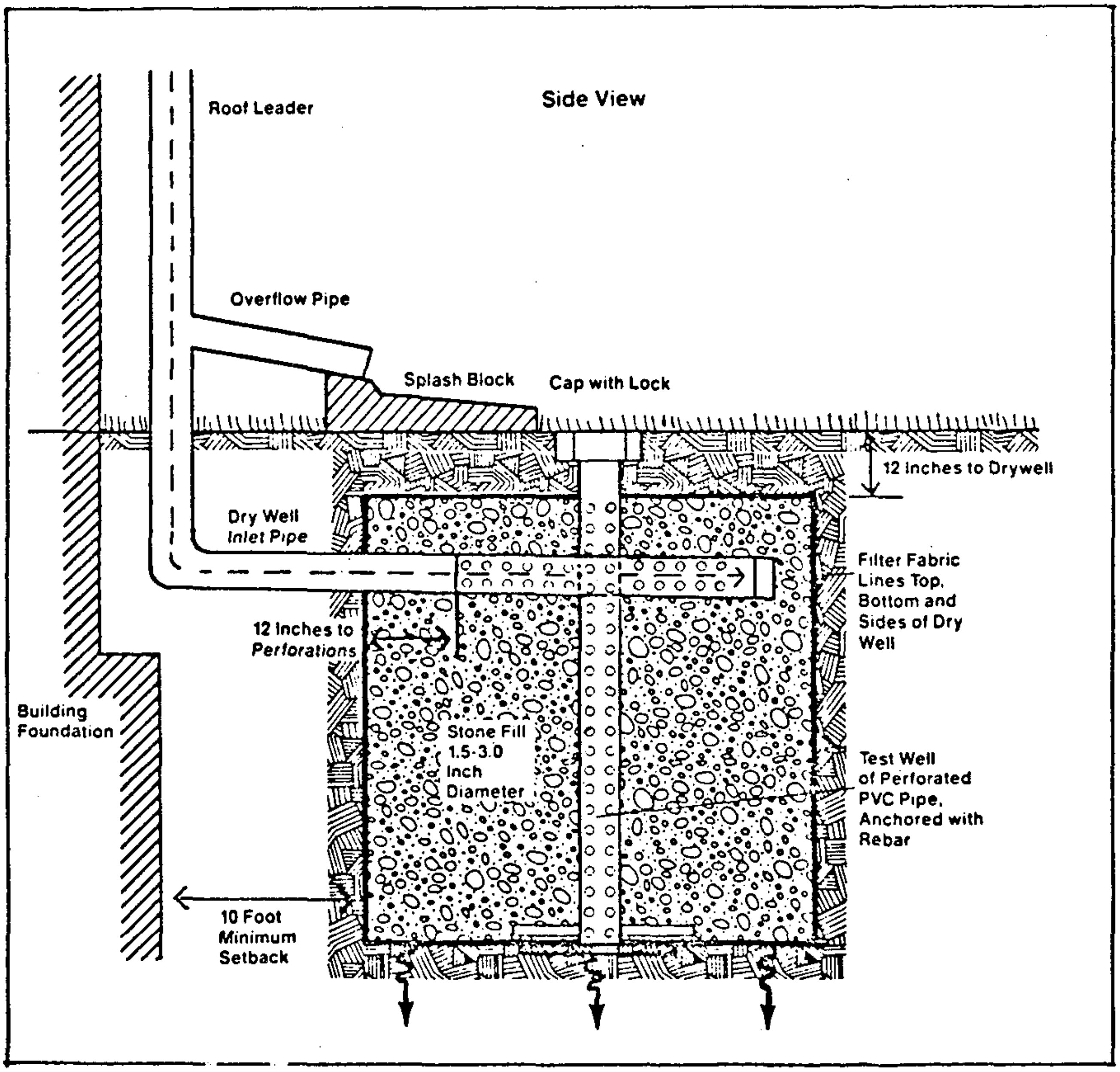
Natural and man-made wetlands can effectively provide storage capacity and filter pollutants from stormwater runoff, if managed properly. The runoff must enter the wetlands as sheet flow to reduce possible erosion and provide maximum contact between the runoff and the wetland vegetation.



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

VEGETATED FILTER/BUFFER STRIPS

FIGURE 6



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

DRY WELLS

FIGURE 7

Sheet flow is runoff which flows in a thin, even layer over the surface. However, in order to protect the natural storage and filtering mechanisms of a wetlands system, a pre-treatment pond should be placed adjacent to the wetlands to reduce sediment load, oils and greases, and attenuate stormwater volumes.

A recent report issued by the Rhode Island Department of Environmental Management (Protecting Wetlands Water Quality, Draft, May 1991) recommends a conservative approach to the use of wetlands for stormwater management. The report recommends the use of other Best Management Practices for sediment removal before runoff is discharged to a wetland.

SUMMARY OF INFILTRATION METHODS

Practice/Key Points	FD	ES	WQ	Reference
1. Vegetated/Grassed Swales o Best Management Practice (BMP) used to provide temporary storage and pollutant removal. o Commonly used in conjunction with other stormwater management practices to provide adequate control of peak discharges.	●		●	8,9,14,15
2. Retention Basin/Wet Pond o BMP used to keep runoff on site to infiltrate into the soil. o Effective at controlling both water quality and peak discharge rates. It does not effectively modify the volume of runoff from a site.	●		●	8,14,15
3. Porous Pavement o Provides water quality enhancement, recharges groundwater, and reduces the volume of runoff generated at a site. o Site must be suitable for infiltration.	●	●	●	4,8,9, 14,15
4. Infiltration Trenches/Basins o Water impoundments which permit infiltration into the soil. o Can effectively provide water quality control, attenuate peak discharges and provide control of runoff volume.	●	●	●	9,14,15
5. Vegetated Filter/Buffer Strips o Best Management Practice similar to swales. Accepts only sheet flow. o Does not provide sufficient storage capacity, unless used in conjunction with other stormwater methods.		●	●	9,14,15
6. Dry Wells o Similar to infiltration trench, only smaller. o Effective at reducing on-site runoff volumes from sites less than one acre.	●		●	9,14

SUMMARY OF INFILTRATION METHODS
(cont.)

Practice/Key Points	FD	ES	WQ	Reference
7. Wetlands Systems o Provide storage capacity and water quality enhancement. o Requires sheet flow to reduce erosion and maximize contact time. o Pre-treatment pond will reduce sediment loads and attenuate storm-water volumes.	●	●	●	8,15

Storage Methods

Storage facilities are a common method for controlling excess stormwater runoff. However, they are not generally used for pollution control, unless designed as part of an overall system that includes stormwater treatment to remove pollutants.

1. Retention Basin/Wet Pond

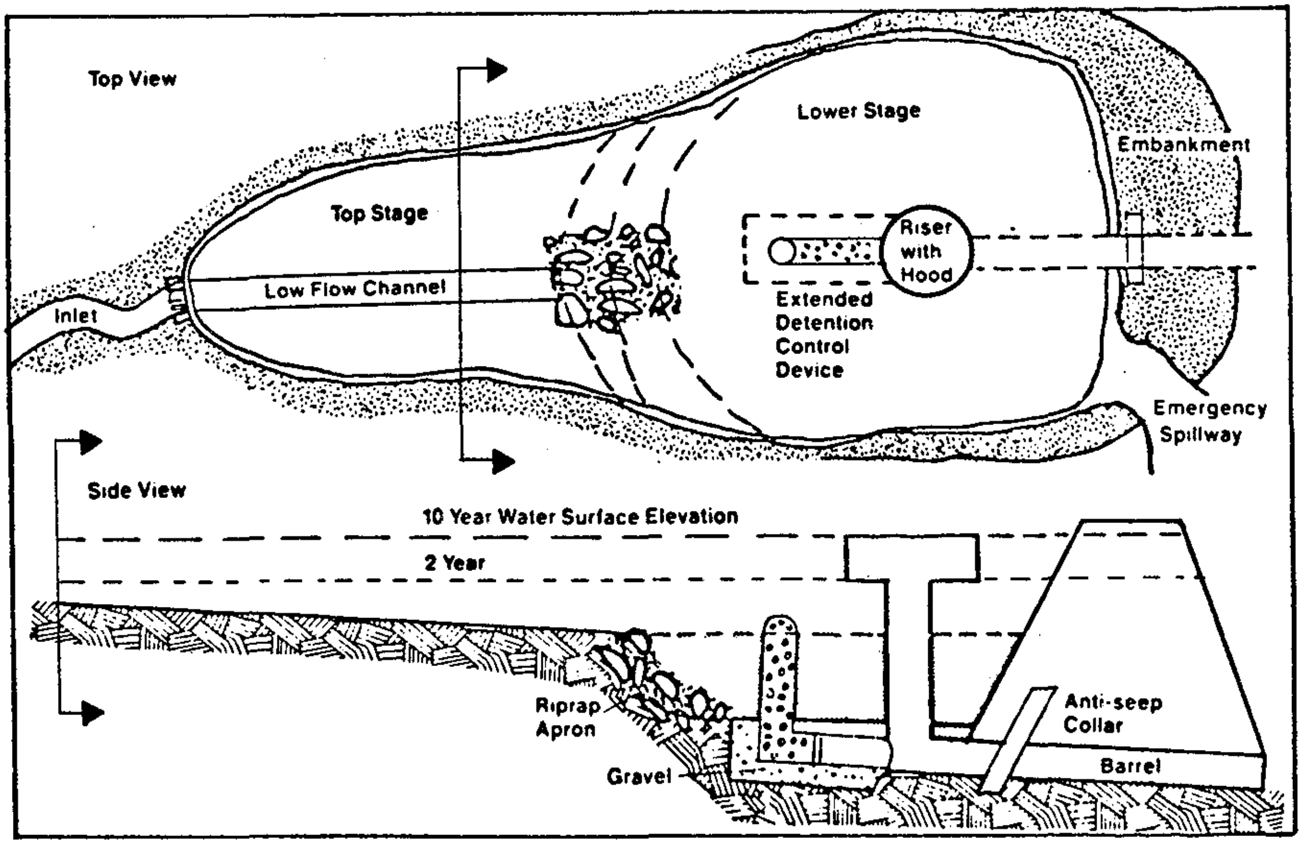
Although retention basins are considered infiltration controls, they also act as storage facilities for the runoff. See Figure 2. Retention facilities store the stormwater runoff which is gradually removed by infiltration and evaporation rather than being discharged to surface waters. They are designed to permanently store the volume of runoff generated by a given storm event at the site. They are an extremely effective method for controlling water quality and are also an effective measure in controlling post-development peak discharge rates. Maintenance and inspection requirements are as previously described under "Infiltration Methods".

2. Detention Basin/Extended Detention Pond

Detention basins are an effective method for controlling the post-development peak discharge rates. They provide temporary storage of the runoff on the site prior to its gradual release at a discharge rate no greater than the pre-development rate. However, they are not specifically designed to decrease the volume of runoff generated at the site and are not always suitable for controlling downstream channel erosion. They may be used in conjunction with infiltration devices (i.e., retention basins, infiltration basins and trenches, porous pavement) which provide on-site runoff volume control.

Extended detention basins can control both pollution and flooding problems. See Figure 8. They meter out the collected runoff at significantly slower rates than conventional dry detention basins, which allows for increased removal of sediments. Extended detention ponds decrease the frequency of bankfull discharges by controlling the post-development discharges associated with smaller frequency storms. This can significantly reduce the frequency of occurrence of erosive floods downstream and is an effective method for controlling erosion of downstream elements. Existing wet ponds or dry detention ponds can be retrofitted to provide the benefits of an extended detention pond.

Maintenance of extended detention basins include wet weather inspections to assess the condition of the facility under operating conditions. It should be maintained as a meadow to reduce mowing and maintenance costs. The responsibility for maintenance should be clearly stated as either the owners or users of the facility. Funds should be reserved for maintenance activities.



(Source: Schueler, T.R., 1987, "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments)

EXTENDED DETENTION PONDS

FIGURE 8

3. Wetlands Systems

Natural and man-made wetlands can effectively provide some storage capacity and filter pollutants from stormwater runoff, if managed properly. The runoff must enter the wetlands as sheet flow to reduce possible erosion and provide maximum contact between the runoff and the wetland vegetation. However, in order to protect the natural storage and filtering mechanisms of a wetlands system, a pre-treatment pond should be placed adjacent to the wetlands to reduce sediment load, oils and greases, and attenuate stormwater volumes.

4. Dry wells

As previously described, dry wells are considered an infiltration method, but they can also provide temporary storage of excess runoff from sites of less than one acre. See Figure 7. They capture and store runoff and provide a means of infiltration for the stormwater. When used in conjunction with other stormwater management methods, dry wells reduce the volume requirements of detention basins and also may contribute to a reduction in the transport of pollutants.

SUMMARY OF STORAGE METHODS

Practice/Key Points	FD	ES	WQ	Reference
1. Retention Basins/Wet Ponds o This method provides storage of run-off which is eventually removed through infiltration.	●		●	8,14,15
2. Detention Basin/Extended Detention Pond o Controls post-development discharge rates. o Do not necessarily reduce the volume of runoff generated at a site. o Extended detention basins release runoff at a much slower rate than a conventional detention pond.	●	●	●	8,14,15
3. Wetlands Systems o Provide storage capacity and water quality enhancement. o Requires sheet flow to reduce erosion and maximize contact time.	●	●	●	8,15
4. Dry Wells o Provide temporary storage of excess runoff from sites less than one acre. o Should be used in conjunction with other measures.	●		●	9,14

V. PRESENT METHODS AND PROBLEMS OF STORMWATER MANAGEMENT IN RHODE ISLAND

1. Example Stormwater Management Methods of Rhode Island

Numerous stormwater management methods are used throughout Rhode Island. Zoning ordinances, subdivision regulations, and infiltration and storage methods are all utilized throughout the State for stormwater management purposes. The following is a general description of some typical examples of stormwater management practiced in various parts of Rhode Island. The sites are grouped by geographic area of the state.

Southeast Section

Site 1 - This site is a residential development with 10,000 square foot lots on approximately 26 acres. The area is served by a detention basin designed to adequately detain runoff from a 25 year rainfall event. The detention pond is well vegetated with inlet and outlet structures surrounded by rip-rap to prevent scour and erosion. The runoff is collected by a catch basin/pipe network throughout the development. The pipe network's outlet enters the detention basin. Runoff is then routed to a low lying wetlands area. Hay bales were placed in strategic areas during construction to prevent silt from entering the newly completed detention basin.

Problems associated with stormwater runoff occurred during early portions of the construction phase. Runoff from recently cleared and graded land significantly eroded large amounts of soil. Runoff controls during this part of the construction phase were not yet in place, causing severe erosion and siltation in portions of the new development.

Site 2 - This site is a 13 acre parking lot draining to a detention basin. The basin's outlet structure has two separate outlets. The lower is designed for low flow associated with a 2 year rainfall event, with a larger opening designed for a 25-year rainfall event. There is a rock lined forebay at the outlet to trap sediment. The outlet leads to a winding rip-rap lined channel designed to reduce flow energy and velocity. A log check dam is provided in the last section of channel before the flow is routed to receiving waters.

Site 3 - This site is a 16 acre residential development having a detention basin designed to accept runoff from a 100 year rainfall event. The pond is quite large for the size of facility it is serving and is not well maintained. The water table is also high in this area resulting in standing water in low areas of the "dry" detention basin. The outlet of the basin drains to a wetlands area and subsequently to a stream.

South Central Section

Site 4 - Runoff from this 10 acre residential development is handled by a wet pond. The wet pond stores runoff for eventual recharge of the groundwater. The pond has an overflow outlet leading to a culvert and subsequently to a local stream. The wet pond is designed to maintain a permanent pool level, provides water quality enhancement, and is an aesthetic asset to the development. (According to Reference 13, a study performed in Maryland surveyed residents living adjacent to stormwater management facilities. The study found that people living adjacent to wet ponds were more likely to view them as aesthetic features than people living near dry detention ponds).

Site 5 - This site contains a large shopping center and parking lot. Runoff from the parking areas drains to a wetlands and dual retention pond system. The majority of runoff is first treated for water quality enhancement by flowing through the wetlands before entering the retention ponds. There is an overflow outlet to a local river. This type of system provides both water quality enhancement and groundwater recharge. Roof runoff from the shopping complex structure is also routed to a retention pond for eventual groundwater recharge. A well-maintained grassed swale is also utilized for treating runoff from a smaller portion of the area and roadway.

Steep side slopes leading to the retention ponds showed signs of erosion due to concentrated runoff. The runoff from adjacent roads is collected and allowed to flow directly to the retention ponds, causing erosion of the side slopes.

Northwest Section

Site 6 - This site incorporates various stormwater management methods. A large area of the facility drains to dry wells for eventual infiltration. However, the dry wells are situated at the bottom of a steeply sloped grade allowing extensive amounts of material to accumulate in and around the dry well. This impedes the infiltration process and prevents further runoff from entering the dry well. The dry wells were poorly sited and require extensive maintenance to function properly.

A pipe drainage network accepts roof, parking lot, and surface runoff from landscaped areas surrounding the facility. A portion of the roof runoff is collected for use as fire protection. The pipe drainage network is connected to various field grates which are designed to accept the surface runoff. However, many of the grates were not properly sited in low areas of the facility and receive little or no flow. The runoff which would normally be intercepted by the grates is instead allowed to concentrate and cause erosion in poorly graded areas.

The pipe drainage network eventually drains to a swale. However, the swale was poorly vegetated and portions of its banks have eroded. Sediment is also accumulating in other portions of the swale which may restrict flow during storms. The stormwater is then routed to a detention basin. Although the basin is designed as a "dry" pond, poor site preparation and grading has created a permanent pool. Runoff is eventually routed to a nearby stream.

Southwest Section

Site 7 - This site contains a series of dry wells accepting street runoff through catch basins. The catch basins collect the runoff and are constructed with sumps to collect sediment. Maintenance to clean out the sumps is required, but the trapped sediment does not hinder the infiltrative capacity of the dry wells. The dry wells are located under the roadway adjacent to the catch basins, and provide infiltration into the soil profile. A number of these catch basin/dry well combinations are located under the roadway throughout the development.

2. Summary of Rhode Island Stormwater Management Methods

The sites mentioned above are only a small sample of stormwater management methods throughout the state and are not indicative of all practices within Rhode Island. These sites are only meant as a broad example of the various types of stormwater management practices throughout Rhode Island. Problems at stormwater sites can be attributed to poor design or construction techniques, or inadequate maintenance.

Numerous other stormwater management sites have been identified by the former Land Management Project of Rhode Island. They maintained an inventory of Best Management Practices within Rhode Island. The present inventory of Best Management Practices has almost 80 examples and includes locations, descriptions, and annotations of each Best Management Practice. The Land Management Project also issued a series of fact sheets describing various Best Management Practices. These fact sheets are reproduced in Appendix C. This material is available through the Rhode Island Department of Environmental Management's (RIDEM) nonpoint source program.

According to Reference 1, "Stormwater Runoff: Problems and Recommendations for Rhode Island", the Rhode Island Department of Environmental Management's assessment of nonpoint source pollution notes that urban runoff, construction activity, road sanding and salting, and agricultural runoff are impacting waters throughout Rhode Island. In response to stormwater management problems, RIDEM is developing a stormwater program to improve flood control and water quality. The following is a summary of recommendations for Rhode Island's stormwater management program compiled from three sources:

1. Summary of Recommendations of the Stormwater Management and Erosion Control Committee Regarding the Development and Implementation of Technical Guidelines for Stormwater Management, Rhode Island Department of Environmental Management, Office of Environmental Coordination. (June 1988)

a. The Committee recommends the establishment of minimum standards for flood and water quality control which include:

- the establishment of minimum flood control standards specifying no increase in the pre-development peak discharge rates for the 2- and 25-year, 24 hour storm events, and

- the differentiation of water quality minimum standards according to the quality of the receiving waters.

b. The application of minimum standards should include new residential developments of 4 or more dwellings, commercial and industrial developments, and highway construction projects. Excluded from these minimum standards are agricultural activities such as cultivation of crops and animal operations.

c. These minimum standards may be achieved through a combination of site design and structural and non-structural measures. The recommended intent of stormwater management plans is to first reduce the volume of runoff, and second, to treat or control the offsite transport of runoff.

d. The Committee recommends the use of detention basins as a structural measure to meet the minimum flood control standards, and the use of wet ponds to meet water quality standards. The use of infiltration devices is recommended to complement these preferred measures or to meet minimum standards.

2. Summary of recommendations and conclusions of "Stormwater Runoff: Problems and Recommendations for Rhode Island", Rhode Island Department of Environmental Management, August 1991.

a. Towns and municipalities should adopt and implement the Rhode Island Soil and Erosion Control Act (RIGL 45-46). At present, only 17 of 39 towns and cities have adopted this important tool.

b. Adequate enforcement of the Soil and Erosion Control Act. Every town and city in Rhode Island should adopt and properly enforce this act to reduce the loss of soil and sediment to receiving waters. The Rhode Island Soil Erosion and Sediment Control Handbook should be used as guidance for installation and maintenance of erosion and sediment control techniques at all new construction sites.

c. The use of proven stormwater management techniques, as outlined in Recommendations of the Stormwater Management and Erosion Control Committee Regarding the Development and Implementation of Technical Guidelines for Stormwater Management and the forthcoming RIDEM Stormwater Management Design and Installations Manual, will help minimize the severity and frequency of flood waters in flood prone areas.

d. The use of water quality protection practices will substantially reduce impacts from pollutant-laden runoff to receiving waters. Structural practices include wet ponds, infiltration basins, and extended detention dry basins.

e. The use of artificially constructed wetlands, as detailed in Artificial Wetlands for Stormwater Treatment: Processes and Design (RIDEM, 1989), can greatly assist in the reduction of certain pollutants such as nitrogen and phosphorous.

f. The Rhode Island Department of Environmental Management is presently preparing a stormwater management plan that includes applicability criteria, performance standards, and a stormwater design manual.

g. All towns and municipalities should adopt a model stormwater management ordinance which will have to be developed. This will authorize local governments to require stormwater management controls for all new developments within their jurisdiction.

h. Enforcement personnel from RIDEM should be required to inspect all stormwater facilities during and after construction. However, due to manpower or funding restrictions, the Rhode Island Department of Administration, Division of Planning suggests the use of local personnel, such as town engineers, to conduct the inspections which could be supported by permit fees.

i. Local zoning ordinances and land use regulations can be important and effective tools in preventing unsuitable development from becoming established in critical areas.

j. Rhode Island should be seeking assistance from the Environmental Protection Agency in formulating a General Permit to meet the requirements of the National Pollutant Discharge Elimination System permitting process. At present, Providence is the only municipality in Rhode Island required to obtain a permit under these new guidelines.

3. Summary and recommendations of "Protecting Wetlands Water Quality: A Review of Current Knowledge and an Analysis of Regulatory Needs for the State of Rhode Island" (Draft), (RIDEM - May 1991).

a. Stormwater runoff carries sediments, nutrients, and other pollutants. Wetlands which receive urban runoff have been found to contain higher levels of metals, nitrates, and bacteria than other wetlands.

b. Adopt a conservative approach requiring treatment of runoff before discharge to natural wetlands. Regulations should require the use of sediment removal Best Management Practices for discharges to wetlands. Various combinations may be used to achieve treatment goals.

c. Stormwater management practices such as buffer strips, sedimentation basins, and infiltration devices are appropriate for agricultural land use. State stormwater management standards implemented with proven agricultural Best Management Practices should provide adequate protection of wetlands water quality.

VI. SUMMARY

A successful Stormwater Management program must be based on a comprehensive approach which assures that the volume, peak discharge rate, and pollutant load leaving a site are no greater in the post-development phase than they were in the pre-development phase. Such a plan provides a means of assigning responsibility for design, construction and maintenance of stormwater control facilities, determining regulations for future land use and development within the watershed, and providing for the preservation and enhancement of water quality in the receiving waters. A comprehensive Stormwater Management program should address goals, design criteria, inspection, and maintenance.

There are numerous stormwater control methods which are presently available for addressing these issues. Various methods can be categorized under one or more of the following four stormwater control strategies.

1. Regulatory and Institutional Controls

   Regulatory and institutional controls include methods for developing a comprehensive stormwater management program at the local level. Instituting a stormwater ordinance to regulate the quantity and quality of runoff and coordinating and cooperating with other communities within the same watershed are two such methods.

2. Source Controls

   Source controls emphasize the prevention and reduction of non-point source pollution and excess runoff before it reaches a stormwater collection system or receiving water.

3. Infiltration Methods

   Infiltration practices are effective at providing storage capacity for excess runoff and at removing certain pollutants by filtering them through the surrounding soil. They are best suited for small watersheds that do not have concentrated, erosive flows or heavy sediment loads. They also require being situated in areas where the local soil and groundwater conditions are suitable for infiltration. The use of infiltration devices is very site-specific and should include careful consideration during the planning stages of any project.

4. Storage Methods

   Storage facilities are a common method for controlling excess stormwater runoff. However, they are not generally used for water quality enhancement, unless designed as part of an overall system that includes stormwater treatment to remove pollutants.

The former Land Management Project maintained an inventory of Best Management Practices within Rhode Island which includes locations, descriptions, and annotations of each Best Management Practice. They also issued a series of fact sheets describing various Best Management Practices. These fact sheets are reproduced in Appendix C. Further information may be obtained from the Rhode Island Department of Environmental Management's (RIDEM) nonpoint source program.

The Rhode Island Department of Environmental Management's assessment of nonpoint source pollution sources notes that urban runoff, construction activity, road sanding and salting, and agricultural runoff are impacting waters throughout Rhode Island. In response to stormwater management problems, RIDEM is developing a stormwater program to improve flood control and water quality. The stormwater management plan includes applicability criteria, performance standards, and a forthcoming RIDEM Stormwater Design and Installation Manual. RIDEM also recommends that a model stormwater ordinance be developed and adopted by all communities through the legislative process. This will authorize local governments to require Stormwater Management controls for all new developments.

Various stormwater control practices may be used as part of an overall Stormwater Management program by local communities. Many types of stormwater management practices exist throughout Rhode Island and a few examples are described within the main report. However, the suitability of each particular practice must be determined on a site specific basis.

A successful Stormwater Management program must be based on a comprehensive approach which assures that the volume, peak discharge rate, and pollutant load leaving a site are no greater in the post-development phase than they were in the pre-development phase. Such a plan provides a means of assigning responsibility for design, construction and maintenance of stormwater control facilities, determining regulations for future land use and development within the watershed, and providing for the preservation and enhancement of water quality in the receiving waters.

The Stormwater Design and Installation Manual, the Rhode Island Soil Erosion and Sediment Control Handbook, and Best Management Practices fact sheets are available from:

Rhode Island Department of Environmental Management
83 Park Street
Providence, RI 02903-1037

VII. ACKNOWLEDGMENTS

This report was developed and prepared by John H. Kedzierski, P.E., Project Manager. The report was prepared under the supervision and management of the following New England Division personnel:

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APPENDIX A

APPENDIX A

GLOSSARY

Aggregate - The stone or rock needed as fill for an infiltration device such as porous pavement, dry wells, or infiltration trenches.

Bankfull discharge - A flow condition where the stream channel is completely filled to the top of the bank.

Best Management Practice (BMP) - A practice which has been determined to be the most effective means of preventing or reducing the amount of pollution generated by non-point sources. BMP's can be structural devices that temporarily store or treat urban stormwater runoff to reduce flooding and remove pollutants.

Check dam - An earth or log structure used in swales to reduce water velocities, promote sediment deposition, and enhance infiltration.

Detention Basin - An impoundment for stormwater runoff usually consisting of a berm and outlet control structure. Detention basins temporarily store runoff and release it at a more appropriate time to prevent downstream flooding and erosion.

Drainage area - The area which drains into a watercourse at a given point.

Dry wells - Similar to infiltration trenches, but usually smaller. Effective for reducing runoff volumes at sites less than one acre.

Evapotranspiration - The process in which plants take up water in their root systems and water evaporates from the plant surfaces.

Extended Detention Basin - Extended detention basins allow for removal of particulate pollutants. The outlet structure is raised above a predetermined surface elevation to detain runoff from a certain frequency storm.

First-flush - The initial portion of a rainfall event that appears as direct runoff and "washes" the surface of pollutants. This results in a small volume of runoff with very high concentrations of pollutants. The "first-flush" is sometimes characterized as the first half to one inch of runoff which carries up to 90% of the pollutant load of the total runoff.

Forebay - A storage bay provided near an inlet of a BMP which traps sediment before it accumulates within the infiltration device.

Hydrograph - A graph for a given point in a stream or drainage area which shows the rate of discharge of stormwater runoff with respect to time.

Hydrology - The scientific study of occurrence and movement of water in the hydrologic cycle.

Impervious Soil - A surface or geologic layer that does not allow appreciable movement of water or inhibits infiltration or percolation.

Infiltration - The downward movement of water from the surface into the soil profile. (inches per hour) Infiltration consists of rainfall minus interception, evaporation, and surface runoff.

Infiltration Basin/Trench - A "best management practice" utilizing the infiltrative capacities of the soil. They are effective at removing both soluble and particulate pollutants from urban runoff.

Interception - Precipitation retained on vegetative surfaces and either absorbed, evaporated, or sublimated.

Level-spreader - A device used to spread out stormwater runoff uniformily as sheet flow. This is to prevent concentrated, erosive flows from occurring, and to enhance infiltration.

Non-point source pollution - Pollution in surface or ground waters not attributable to known discharges or point sources.

Peak discharge - The maximum instantaneous rate of flow during a rainfall event.

Percolation - Gravity induced flow of water through the pores or spaces of a soil or geologic layer.

Porous pavement - Pavement with a high void aggregate base that allows rapid infiltration of stormwater runoff.

Retention Basin/Wet Pond - An infiltration BMP which stores runoff and allows it to infiltrate into the soil profile. This structure usually retains a permanent pool of water between storm events.

Runoff - Rainfall which does not infiltrate the surface of the soil and percolate through the soil profile, thus leaving a site as overland flow.

Sheet flow - Runoff which flows over the ground surface as a thin, even layer, not concentrated in a channel.

Surface storage - Precipitation that ponds in surface depressions.

Swale - A BMP infiltration device designed as a wide shallow ditch used to temporarily store, route, or filter runoff.

Time of concentration - The time required for runoff from the most hydraulically distant point of a drainage area to reach the outlet.

Vegetated Filter/Buffer Strip - Filter/Buffer strips are similar to swales, but are designed only to accept runoff in the form of sheet flow.

Watershed - The catchment area for rainfall which is delineated as the drainage area producing runoff.

APPENDIX B

APPENDIX B

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APPENDIX C

THE LAND MANAGEMENT PROJECT

THE LAND MANAGEMENT PROJECT
BIBLIOGRAPHY OF PUBLICATIONS

1. FACT SHEETS

Land Use and Water Quality Series Fact Sheets
Summaries of water quality concerns regarding key land uses.

Septic Systems (1989)
Home Lawns (1989)
Road Salt and Salt Storage (1989)
Roads and Highways (1989)
Commercial Land Use (1989)
Stormwater and Wetlands (1990)
Biological Mosquito Control (1990)
Subdivision Regulations (1990)
Zoning Regulations (1990)
Site Plan Review (1990)
Sand & Gravel Mining (1990)
Sand & Gravel Reclamation (1990)
Low-Maintenance Landscaping (1991)
Cluster/Open Space Zoning (1991)
Watershed Management (draft)
Growth Management (draft)
Nutrient Loading (draft)

Best Management Practices (BMPs) Series Fact Sheets
Descriptions of specific BMPs and their applications.

Stormwater BMPs (1990)
Grassed Swales (1990)
Artificial Wetlands (1990)
Vegetated Buffer Strips (1990)
Extended Detention Basins (1990)
Infiltration Devices (1990)
Alternative Turf (1990)
Wet Basins (1990)
Stormwater Utilities (1991)
Estimating Costs for BMPs (1991)

2. RESEARCH REVIEWS

Data summaries of scientific research on key nonpoint sources of pollution. Research reviews completed thus far:

Nitrate Nitrogen Pollution from Septic Systems (1989)
Phosphorus Pollution from Septic Systems (1989)
Nitrogen Pollution from Home Lawns (1989)
Pollution from Roads (1989)
Pollution from Commercial Land Use (1989)

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The Land Management Project is sponsored by the U. S. Environmental Protection Agency and the R.I. Department of Environmental Management.

3. WETLANDS

<u>Wetlands Site Review Guide</u> (1989)
This guide will help conservation commissioners and others evaluate how a development proposal will impact wetland functions and values.

"Listing Wetlands by Plat and Lot: Creating a "Wetland Alert" List" (1989)
How wetlands maps and plat/lot maps can be used to identify which lots have wetlands on them.

<u>Stormwater Basin Landscaping Guide</u> (draft)
A guide to plant species selection and other considerations in stormwater basin landscaping. Designed for those requiring, designing, or reviewing stormwater basin plans.

"Wetlands: Selected Publications" (1990)
Listing of wetlands publications and where to order.

"Local Wetland Regulation in Rhode Island" (1990)

"What Towns Can Do to Protect Wetlands" (1989)

4. LOCAL ORDINANCES

"Survey of Local RI Regulatory Capabilities" (1991)

"Regulatory Capabilities Survey Matrix" (1991)

"Survey of Staffing Capabilities and Needs in Rhode Island Towns" (1990)

"Staffing Capabilities and Needs in RI Towns Matrix" (1991)

"Sources of Model Ordinances Pertaining to Water Quality Protection" (1991)
Bibliography and listing of sources of model ordinances pertaining to water quality and growth management.

"Inventory of Local Ordinances Pertaining to Water Quality" (1991)
An inventory of ordinances pertaining to water quality and growth management, from Rhode Island and elsewhere, that have been collected by the Land Management Project.

5. NUTRIENT LOADING

"Nutrient Loading Models Bibliography" (1990)
A partial bibliography of publications on nutrient loading models.

"Nutrient Loading and Contamination Transport: Abstracts of Selected Models and Methods" (1990)
Abstracts of LMP Nutrient Loading Models Bibliography, noting data requirements, ease of use, advantages, shortcomings, and applicability for Rhode Island communities.

"Nutrient Loading Methods and Recommendations" (draft)

6. MATERIALS ON LAND USES AND NONPOINT SOURCE CONTROLS

"LMP Buffer Matrix: Examples of the use of Vegetated Buffer Strips in Controlling Nonpoint Source Pollution" (1990)
This matrix highlights buffer sizing criteria for many jurisdictions by indicating proposed widths, physical conditions, implementation strategies, and general comments

"LMP Land Use Matrix: Land Uses and Potential Contaminants" (1989)
This matrix identifies what contaminants may be associated with certain land uses.

"Road Salt Storage and Application Recommendations" (1989)
A summary of guidelines from Rhode Island and elsewhere.

"Bibliography and Ordering Information - Publications on Planning, Water Quality, and Nonpoint Source Pollution Control" (1990)

"A Partial Listing of Major Non-Point Sources and Controls" (1989)
Structural and Non-Structural measures to mitigate non-point source pollution from Urban Runoff, Marine Activities, ISDS, Construction, and Earth Removal.

"Stormwater Management: In-Town Workshop Resource Materials" (1991)
"Growth Management: In-Town Workshop Resource Materials" (1991)
Compilations of selected articles, presentations, and information providing overviews of LMP In-Town Workshop Topics.

7. CRITICAL AREAS SERIES

"Protecting Critical Areas via the Comprehensive Planning Process" (1990)
"Selected Critical Area Management Strategies" (1990)
"Selected Critical Area Definitions and Program Summaries" (1990)
"Areas of Critical State Concern" (1990)

"Growth Management I" (1990)
"Growth Management II" (1990)
Overview of Growth Management techniques and strategies available to communities

"Preparing a Preliminary Build-Out Scenario for your Community: A Guide for Citizens Advisory Committees" (1990)
An introduction to the build-out Scenario, including data requirements and step-by-step instructions

8. LMP PROJECTS AND CONFERENCES

"Prospectus: Land Management Project Demonstration Projects" (1989)
"LMP Demonstration Projects List" (1989)
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9. WATERSHED MANAGEMENT

"Hunt-Potowomut Watershed Management Initiative Proposed Analytical Procedure and Protection Strategy" (1989)

"Watershed-based Techniques for Joint NPS/Growth Management" (1989)

"Pilot Evaluation of Low-tech Regional Nonpoint Source Control Opportunities" (1990)
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THE LAND
MANAGEMENT
PROJECT

Septic Systems

Fact Sheet No. 1 • August 1989

The Problem

Septic systems or "individual sewage disposal systems" (ISDSs) are designed to discharge household wastewater to the ground, where contaminants are attenuated to some degree by the soil. ISDS leachate includes nitrogen, phosphorus, pathogenic bacteria and viruses, metals, detergents, solvents, system additives and other chemicals. Nitrates, pathogens and chemicals may contaminate drinking water, and nutrients (nitrogen and phosphorus) may lead to eutrophication of surface water bodies.

Substandard septic systems in older residential areas have led to the contamination of surface and groundwater quality in Rhode Island (Middlebridge, Hope Valley and elsewhere). New development at unprecedented rates, often in substandard site conditions, threatens the quality of sensitive surface waters, including the Scituate reservoir and other water supply reservoirs.

Key Findings

• Even properly functioning septic systems deliver significant amounts of nitrate to the groundwater. This can affect drinking water in residential areas relying on groundwater, especially in coarse sandy soils.

• Septic systems are a major source of nutrients, which stimulate eutrophication. Very small amounts of phosphorus can affect freshwater lakes and ponds, while nitrogen is the limiting nutrient in coastal ponds. Many of Rhode Island's surface waters, both inland and coastal, are highly susceptible to eutrophication.

• Pathogens (bacteria and viruses) can travel great distances in saturated flow, and are a major threat from improperly functioning septic systems.

• Some ISDS cleaners are based on organic solvents, which may travel rapidly through groundwater and have been linked to well water contamination.

Water Quality Concerns

Nitrates in drinking water

Nitrogen in wastewater is primarily in the ammonia form, but as it passes through the soil most of it becomes oxidized and converts to nitrate (NO_3). The EPA nitrate-nitrogen drinking water standard is 10 mg/L and is intended to prevent methemoglobinemia ("blue baby syndrome") and other health effects. The high nitrogen loading rates and very limited treatment of nitrate in ISDSs make this a major concern. Research has found:

• The concentration of nitrogen leaving the septic system and entering the soil is high, in the range of 30-80 mg/L.
• Once in the soil, the primary mechanism of nitrogen removal is denitrification (conversion to nitrogen gas). Rates of denitrification vary widely.
• In the groundwater, the only means of reducing concentrations significantly is through dilution. If ISDS nitrogen inputs are high, if little dilution occurs, or if other inputs (lawn fertilizer, pet waste) are significant, then groundwater concentrations may be high.
• Nitrates are persistent in groundwater and can travel potentially unlimited distances.

Factors affecting nitrate levels

There are many highly variable, site-specific factors that influence the concentration of nitrate in groundwater. These include:
• *How the system is used:* The number of users, seasonality of use, the amount of nitrogen in the wastewater, and the overall flow rate.
• *The septic system:* The size of the tank and the frequency of pumping determine how much space and time there is for settling out of solids, which reduces output of some wastes. The size of the leach field determines how much soil the wastewater will pass through and be treated by.
• *Soil characteristics:* Soil that is too porous or permeable may transmit wastewater too quickly, allowing little time for waste constituents to be attenuated. Soils that are too tight or impermeable may prevent exposure of wastewater to oxygen, which is necessary for removal of some pollutants.
• *Depth to groundwater:* This determines, in part, how much time the wastewater will spend in the aerobic r of the soil where most treatment occurs.

Pathogenic bacteria and viruses

Septic systems are the largest single cause of water-related disease outbreaks in the U.S. Disease-causing microorganisms (pathogens) have been found to contaminate both drinking water supplies and recreational waters. Pathogens are usually destroyed in unsaturated, aerobic soil conditions within one meter of the source. However, pathogens have been found to survive in either very coarse or very dense soils, where channels of flow occur in the soil, or where systems have failed. Once in saturated flow (such as groundwater or a stream), pathogens may travel long distances, and cases of travel of hundreds of meters have been documented. In fact, travel distance is limited only by survival time. Researchers in Connecticut determined survival time of most bacteria in saturated conditions to be 3-6 weeks, and viruses may survive for longer times. It is important that:

• There is adequate separation between the leach field and the water table to remove pathogens. Recent research has found pathogens may move more than four feet through coarse soils after very heavy rains.

• Septic systems are located far enough from wells so that the travel time of groundwater between system and well is greater than the pathogens' survival time.

Other contaminants

Many household products contain toxic chemicals, including general cleaners, drain and toilet cleaners, septic system cleaners, spot removers, solvents, furniture polish, silver polish, bleach, and pesticides. Research on the fate of these chemicals has shown most of them to be very persistent in groundwater and to be able to travel great distances. Organic solvents used as septic system cleaners are frequently linked to pollution from septic systems; their use should be prohibited. Biological cleaners, which are more common, are one alternative. Some case studies of contamination include:

• One study of a community wastewater system found 40-50 volatile compounds, 5 of which were EPA priority pollutants, at concentrations of over 1 ppb.

• The common septic system cleaner constituents methylene chloride (MC) and trichloroethane (TCA) were monitored in system effluents in another study. It was found that 75% of the methylene chloride was discharged from the system into the ground, while most of the trichloroethane remained in the septic tank.

• Another study used application rates recommended by the manufacturer and found high MC and moderate TCA levels four feet below a cesspool.

Eutrophication of surface waters

Phosphorus and fresh water

Phosphorus is the primary limiting nutrient (the nutrient in shortest supply) for aquatic plants in fresh water. Extremely low levels of phosphorus can stimulate aquatic plant growth. *Eutrophication*, excessive growth of plants in overproductive surface waters, is a natural process accelerated by the influence of humans. As the plants rapidly grow and die, the dead plant parts are decomposed by oxygen-consuming bacteria, which can greatly reduce oxygen levels. Low oxygen levels degrade aquatic habitats, and may stimulate phosphorus release from bottom sediments, which in turn leads to further plant growth and algal blooms. Rhode Island's lakes, ponds and reservoirs are generally small, shallow, have low flushing rates, and are highly productive, making them highly susceptible to eutrophication.

• Phosphorus inputs in the parts per *billion* (ppb) can stimulate eutrophication in fresh waters, and phosphorus levels indicating eutrophic conditions are in the 20-100 ppb range.

• Phosphorus levels in wastewater effluent are on the order of 5-25 parts per million (5,000-25,000 ppb). Even though more than 90% is typically removed by the soil column, relatively large concentrations may remain.

• Old, poorly maintained, or poorly sited systems frequently "fail" to some degree. Failing septic systems yield relatively huge pulses of phosphorus to surface waters or groundwater (which generally emerges eventually as surface water). A stream of saturated effluent leaves the ISDS, either pooling on the surface or flowing through the ground. There is little attenuation of phosphorus in saturated flow.

• There is some evidence that the phosphorus attenuation capacity of soil is limited. Several studies have found phosphorus "breakthrough" - increasing rates of leaching - over time. Time to breakthrough was highly variable and depended on soil conditions and rate of effluent flow.

Nitrogen and coastal waters

Nitrogen has been identified by URI researchers as the limiting nutrient for aquatic plant growth in coastal waters. Nixon and others estimated in 1982 that ISDSs contributed 12-44% of the annual nitrogen input to Rhode Island's eight south shore salt ponds. The highly permeable soils, dense developments, and economic and recreational importance of those ponds makes them of special concern.

The Land Management Project assists towns in water quality protection and related issues. For more information on this and other topics, contact The Land Management Project at 83 Park St., Providence RI 02903, telephone (401)277-3434.
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THE LAND MANAGEMENT PROJECT

Home Lawns

Fact Sheet No. 2 • August 1989

The Problem

Large amounts of fertilizer and pesticides are applied to home lawns in Rhode Island each year. Most are highly soluble, allowing them to run off into surface waters or to percolate into groundwater. Many of Rhode Island's freshwater and coastal ponds are plagued with excessive algal and aquatic plant growth; fertilizers applied to lawns are believed to be significant contributors of the nutrients limiting aquatic plant growth (nitrogen and phosphorus). Nitrate, along with pesticides, may also contaminate drinking water supplies.

Key Findings

• Nitrogen is readily dissolved and leached into groundwater, especially in highly permeable soils or in overwatered or overfertilized lawns. Lawns can contribute substantially to the nitrate load.

• Lawn fertilizers are believed to be a major source of nutrients, and can stimulate eutrophication (excessive plant growth) in surface waters.

• The most popular lawn grass, Kentucky bluegrass, is also one of the most demanding, requiring high rates of fertilizer, pesticides and watering.

• Many pesticides are highly soluble and persistent in water. The potential health effects of most of the over 600 active ingredients and 4,000 products available are being studied. Many pesticides are among the 120 EPA priority pollutants.

Threats to Drinking Water Supplies

Nitrates

Nitrates are a concern because of the threat of methemoglobinemia ("blue baby syndrome") and other health effects. Groundwater supplies in residential areas frequently exceed the national drinking water standard of 10 milligrams per liter (mg/L), and home lawns (along with septic systems) are a major contributor.

Key Factors

Nitrogen leaching rates to groundwater and its final concentration in groundwater are influenced by a number of factors:

• **Fertilizer application rates:** If more fertilizer is applied than can be taken up by turfgrass, other vegetation, or the soil, the excess may leach to groundwater. Here in Rhode Island studies have shown how high application rates yield higher nitrogen levels in soil water and groundwater than moderate application rates. Recent URI research in silt loam soils using urea fertilizer found that under moderate application rates (2 lb/1,000 ft^2/year), nearly all of the nitrogen was removed within 2 feet of the surface. High rates (8 lb/1000 ft^2), however, yielded high concentrations of nitrate-nitrogen (9 mg/L) in the soil water leachate.

• **Irrigation rates:** Overwatering has been shown to increase nitrogen leaching in a variety of soil types. In a Rhode Island sandy loam outwash soil, it was found that watering rates of about 1.5 inches per week caused nitrogen leaching rates to roughly double compared to minimally watered plots.

• **Lawn area:** As housing density increases, the percentage of each lot in turf also increases. There is also evidence that homeowners apply chemicals at relatively higher rates on smaller lawns.

• **Soils:** Coarse, sandy soils (such as outwash soils in the coastal pond area) are highly permeable (transmit water easily). Such soils are likely to allow higher nitrate leaching rates. On the other hand, till, wetland, or other fine soils transmit little water, and are likely to lose more contaminants via runoff or overland flow. Soil types at either extreme are of concern.

Pesticides

Pesticides include insecticides, herbicides, fungicides, nematicides, etc. - any substance that kills or repels any kind of pest. There are over 600 active ingredients in use, and over 4,000 products registered for use in Rhode Island. Studies of health effects have lagged behind pesticide development and use, and few drinking water standards have been set. Below is a listing of current information on some of the more common pesticides or pesticide ingredients in common household use in Rhode Island. All are currently available to the general public.

Health information on many of these substances - especially the long-term or "chronic" effects - is incomplete. Their use should be carefully regulated. Placing some pesticides in "restricted use" (for professional use only), educating homeowners on proper use and alternatives, and limiting lawn sizes are some approaches.

Common household pesticides, contamination potential, and health concerns

Name (& example)	Type*	Solubility (mg/L)	Half-life in soil (days)	Surface loss potential	Leaching potential	EPA L.H.A. (ppb)	Health Concerns
2,4-D	H	50 (E)	10	Med.	Small	70	Liver, kidney, other damage; implicated in cancer studies
Captan (Orthocide)	F	NA	NA	NA	NA	NA	Under special review by EPA
Carbaryl (Sevin)	I	40	7	Med.	Small	700	Liver, kidney damage in animals; inhibits enzyme cholinesterase
Chlorpyrifos (Dursban)	I	2	30	Large	Small	NA	
Diazinon	I	40	30	Med.	Large	0.6	Degrades enzyme cholinesterase; responsible for many human poisonings and bird kills
Dicamba	H	800,000	14	Small	Large	200	Liver and other adverse effects in in animals
Glyphosphate (Roundup)	H	1,000,000	30	Large	Small	NA	
MCPP	H	660,000	21	Small	Large	NA	
Malathion	I	145	1	Small	Small	NA	Degrades enzyme cholinesterase
Metaldehyde	I	230	10 (E)	Med.	Small	NA	
Methoxychlor	I	NA	NA	NA	NA	400	Inhibits growth in animals
Pendimethalin	H	0.5	60	Large	Small	NA	
Prometon (with simazine)	H	750	120	Large	Large	100	Affects growth in animals

* H = Herbicide, I = Insecticide, F = Fungicide
(E) = *Estimated value, may be off by a factor of three*
NA = This information not available for this pesticide
L.H.A. = EPA Lifetime Health Advisory Guideline for long-term ingestion

Sources of information:
U.S. EPA (*no date*). Pesticide Fact Sheets.
USDA Soil Conservation Service (no date). Field Office Technical Guide I-5: Pesticide Database.
Cornell University Center for Environmental Research and Dept. of Agron. Bulletin #3: Pesticides: Health Effects in Drinking Water.

Threats to Surface Waters

Eutrophication, excessive growth of plants in overproductive surface waters, is a natural process accelerated by the influence of humans. It is caused by inputs of nutrients that stimulate aquatic plant growth - phosphorus in fresh water and nitrogen in coastal waters. Eutrophication results in ponds choked with weeds and low in oxygen. It reduces recreational and aesthetic value, degrades fish habitat, and can damage economic values of the water body.

Extremely low concentrations of phosphorus may stimulate plant growth and induce eutrophic conditions in fresh waters. Most phosphorus is removed as it passes through the soil column, but little attenuation occurs in surface runoff. Residential areas close to surface waters may yield runoff with relatively high phosphorus levels. Most of Rhode Island's ponds and reservoirs have slow flushing rates and are naturally very productive. Given the sensitivity of Rhode Island's surface waters to nutrient inputs, even small quantities may lead to eutrophic conditions.

Nitrogen is the limiting nutrient in coastal waters. The state's coastal ponds are recreationally and economically valuable. The already high density and continuing rapid pace of development around them make them of great concern. Nitrogen runs off from lawns or leaches into groundwater, from which it flows into the ponds with groundwater discharge.

What Towns Can Do

- Educate homeowners as to proper use and disposal of lawn care products.
- Require natural buffers around lawns, especially near surface waters.
- Limit lawn size in medium or high density development.
- Encourage the use of alternative, low maintenance turf types, less fertilizer and pesticides and avoidance of overwatering.

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THE LAND MANAGEMENT PROJECT

The Land Management Project • Land Use and Water Quality Series

Road Salt and Salt Storage

Fact Sheet No. 3 • August 1989

The Problem

Rhode Island's bare pavement policy for winter road maintenance has resulted in heavy salt applications on most state and local roads. The state applies roughly 150-300 pounds of salt per lane mile, and towns apply sand and salt to local roads. Sand/salt mix ratios vary widely and are often unknown. Runoff from heavily salted roads and from unprotected salt storage piles can cause temporarily high concentrations of sodium and chloride in surface waters and longer-term changes in groundwater.

As an example, chloride concentrations in Bear Tree Brook downstream from the state's Clayville salt storage facility, in the Scituate watershed, have commonly been in the 100-250 mg/L range. Sodium there has typically been over 20 mg/L.

Key Findings

• Uncovered salt storage piles have resulted in many cases of groundwater contamination. The DOT has estimated that 20% of the salt in uncovered piles may run off annually, and nearly three-fourths of the piles in the state are uncovered.

• Sodium concentrations have been found to correlate closely with road area in the Scituate watershed, and are attributed mainly to de-icing. Alternative de-icing mixtures may be considered in critical areas. Warning signs, reduced speed limits, and education must be a part of such a program.

• Sodium and chloride may have many subtle effects on water quality, including induced stratification, heavy metal release, and long-term effects on organisms.

Threats to Surface Water Quality

Runoff from road applications

Winter road runoff can result in concentrations of chloride in the thousands of milligrams per liter (mg/L) in receiving waters. This far exceeds the U.S. EPA's secondary drinking water standard of 250 mg/L as well as the toxicity levels of many organisms (these typically range from the hundreds to thousands of mg/L). Concentrations may be quickly diluted, but the chloride loads may persist and accumulate indefinitely.

Some examples:

• In a stream running through metropolitan Toronto, a winter thaw yielded 50-fold increases in sodium concentrations, which stayed higher than baseline levels for several days.

• The chloride concentration in Irondequoit Bay, Rochester, NY, increased 5-fold over 20 years. The increase was attributed to road de-icing. Concentrations reached 400 mg/L at the bottom of the bay, and average bay concentrations were consistently over 100 mg/L and rising steadily. Chlorides appeared to be accumulating in the groundwater and in the bay.

Runoff from salt piles

Salt piles, if unprotected, may also result in locally high concentrations in runoff and surface waters. The RI DOT, as reported in the Scituate watershed plan, has estimated that 20% of the salt in unprotected piles is lost in runoff every year. The RI DEM is inventorying salt piles in the state, and has found that only 23 of 84 active piles are covered. Most of the state DOT's 25 active piles remained uncovered in 1988. Documented cases of contamination generally pertain to groundwater (see below), but a URI study published in 1981 reported "confirmed" surface water contamination at nine of DOT's 27 storage sites and possible contamination at four others.

Induced stratification and other impacts

Chlorides make runoff and receiving waters more dense, thereby increasing the density gradient (the difference in density between upper and lower layers) in ponds and lakes, and promoting stratification. This has been shown to prevent spring vertical mixing and to delay fall mixing in Irondequoit Bay, NY. Reduced mixing may lead to oxygen-deficient bottom waters and prevent the redistribution of nutrients in lakes.

Other possible effects of sodium and chloride inputs include the release of mercury from bottom sediments and the stimulation of blue-green algae.

Groundwater Contamination

Groundwater contamination may occur when dissolved sodium and chloride seep through soils or stormwater drainage and control facilities. Contamination of water supplies has been widely documented, both from road salting and from salt storage piles. It affects drinking water quality, increases corrosive properties of water, and impairs some industrial uses of water.

Groundwater contamination in Rhode Island

Recent research in the Scituate watershed measured sodium and chloride concentrations in stream "baseflow," the flow derived solely from groundwater discharge. There, URI researchers found strong correlations between both sodium and chloride concentrations and road area. In three of the 22 water bodies sampled, sodium levels consistently exceeded 20 mg/L (the level recommended by the American Heart Association). They calculated the area of roadway that would yield undesirable sodium levels (over 20 mg/L) and found it to be 1.35% of the total area of a given watershed. This predictive model was tested successfully in the Hunt watershed, suggesting it may be applicable to other areas.

In other URI research, two of the state DOT's storage piles showed "confirmed" groundwater contamination, and 10 others (of 27) showed possible contamination.

Groundwater contamination elsewhere

• A recent review of groundwater quality in Connecticut by the USGS found 12% of samples in aquifers to exceed 20 mg/L sodium, and associated the high levels with salt storage. The Irondequoit Bay research suggests that chlorides tend to accumulate in groundwater.

• In Massachusetts, chloride levels in community water supply wells in the Burlington area had increased severalfold from 1963 to 1970, and were approaching the 250 mg/L standard.

• In New Hampshire, some roadside domestic wells had over 3,500 mg/L chloride.

Roadside Soil and Vegetation

Salt may accumulate in the soils and may damage the vegetaiton along roadways. Certain species are particularly susceptible to salt damage, including red maple (Rhode Island's state tree), sugar maple, linden, black walnut, red pine, white pine, and hemlock. Herbaceous vegetation along roadways will be limited to only the most salt-tolerant varieties. Salt also encourages the growth of Phragmites, which is agressive and has low wildlife value.

Property Damage

Salt applied to roads has been shown to corrode pavement, road structures, utility structures, and automobiles. An EPA study published in 1976 estimated the total damage from highway de-icing to be $3 billion per year, or 15 times the annual cost of the salt itself. The damage to vehicles was estimated by various researchers to be around $100-$200 per vehicle per year.

What Towns Can Do

Public water supply reservoirs, groundwater aquifers, and sensitive water bodies near roadways or salt storage piles are susceptible to the effects of sodium and chloride in runoff. These areas should be identified, delineated, and protected from excessive salt runoff.

• Proposed state guidelines for salt storage should be followed, including:
- Salt storage piles should be completely covered.
- Salt should be stored and handled on an impervious surface.
- Runoff should be contained in an appropriate area.
- Residue should be cleaned after operations. It may be directed to a sand pile or dried and returned to salt piles.

The state's Scituate watershed road salt policy is a good model:

• Application rates should follow the state's published guidelines for the watershed (adapted from the EPA), according to road size and storm conditions. The recommended application is a "premix" of 4 parts sodium chloride to 1 part calcium chloride in a 7:2 sand:salt mixture.
Cost: 4:1 premix, $75/ton; sodium chloride, $30/ton.

• Trucks should be equipped with ground-speed sensors, which automatically control the spread rate of material.
Cost: About $6,000 per truck.

• All drivers and handlers of road salt should attend the Salt Institute's training program to improve efficiency and reduce losses.
Cost: free

Calcium chloride is more expensive than sodium chloride, but is less environmentally harmful and works better at lower temperatures. Sand:salt ratios may also be increased, so there is more reliance on abrasive than on the melting action of salt. This helps traction but is less likely to produce bare pavement. Excessive sanding may pose sedimentation problems, reducing capacity of drainage structures and destroying aquatic habitat.

Reduced salt applications require other measures as well, including educational materials, signs notifying motorists, and reduced speed limits.

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THE LAND
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Roads and Highways

Fact Sheet No. 4 • September 1989

The Problem

Roadways contribute a wide range of pollutants to the air, surface water, and groundwater. Heavy metals, hydrocarbons, bacteria and salt are common constituents of road runoff; copper, lead and zinc are the most common heavy metals. Traditional curbing and piped drainage systems escalate delivery of untreated road runoff to watercourses. Higher runoff rates also contribute to flood hazards and affect watershed streamflow patterns. Activities associated with road use (service stations, car washes, junkyards, etc.) are also significant sources of pollution.

Key Findings

- **Research in Rhode Island found that highway runoff was responsible for over 50% of solids, lead, zinc and polycyclic aromatic hydrocarbons entering the Pawtuxet River.**
- **Sodium and chlorides are the most prevalent contaminants from roads and frequently exceed recommended standards near roads and road salt storage areas (see the *Road Salt* Fact Sheet).**
- **The "impact area" of significant deposition of metals and particulate matter is 35 m from the pavement edge in urban areas, 15 m in rural areas.**

Heavy Metals and Water Quality

Much research has been done on heavy metal pollution from highways. Major findings include:

• In Rhode Island, state highways contribute 77% of zinc, 66% of lead, 39% of cadmium, and 36% of copper inputs to the Pawtuxet River. Research in Britain found 1/2 to 3/4 of heavy metal pollution to derive from roads.

• Most of the heavy metal load in runoff is bound up with suspended particulate matter. The majority is initially deposited as airborne pollution before settling to the land surface. From there it runs off to surface waters, enters the soil, or is taken up by vegetation.

• The metal content of soil and vegetation along highways is strongly correlated with traffic volume and distance from the roadway, among other factors.

• The effects of metals from highway runoff on aquatic communities is variable, and evaluation is complicated by the diversity of forms and toxicities of metals. The toxicity of metals depends in part on water hardness, and the EPA describes the northeastern U.S. as "sensitive" in that regard. In surface waters, a reported 95% of heavy metals settle out in the bottom sediments, where submerged plants and bottom-dwelling organisms have shown high metal concentrations. The settleability of metals contributes to the effectiveness of detention and retention ponds in treating road runoff.

Some of the research results on metal toxicity include:
- inhibition of algal growth at low concentrations (30-50 parts per billion) of copper, zinc, and cadmium;
- high zooplankton mortality in runoff from high traffic volume roads;
- low hatching rate and high mortality of juvenile trout at zinc concentrations as low as 40 ppb.

Hydrocarbons

Hydrocarbons in highway runoff were studied by URI researchers in Rhode Island. They found that 16% of the total petroleum hydrocarbons, and 77% of the polycyclic aromatic hydrocarbons entering the Pawtuxet River derived from highway runoff. Sediment cores taken from the bottom of the river also showed sharp increases in hydrocarbons after I-95 was built, although the region underwent rapid development during the same time period.

The majority of the hydrocarbon load is bound up with solids. Research in Switzerland, for example, found 95% of hydrocarbons were bound up with suspended solids in "agglomerates." Most of the hydrocarbon load is settleable. Studies in New Jersey found that in impounded runoff waters, 65% of the hydrocarbon load settled out after 32 hours of standing.

Pathogens

Bacteriological monitoring conducted during the Nationwide Urban Runoff Program, in the Rhode Island salt ponds, and in Buttermilk Bay, Massachusetts found stormwater runoff to be a significant source of pathogens. This source has been a contributing factor in pathogen-related closure of parts of Narragansett Bay to shellfishing. The Buttermilk Bay results suggest that stormwater is the primary factor in shellfishing closures, and that coliform levels are related to residential development. Dry weather surveys of the drainage areas there showed that the primary source of fecal coliform is not sanitary waste, but waste from pets and wildlife. Drainage improvements such as curbs and pipes rapidly deliver road runoff to receiving waters, increasing the pathogens' chances of survival.

Nutrients

The impacts of nutrients from road runoff have received less attention than other pollutants. However, nutrients (principally nitrogen and phosphorus) can degrade surface waters by stimulating aquatic plant growth. Excessive growth or "eutrophication" chokes waters and lowers oxygen levels. Nitrogen is the limiting nutrient (the nutrient in shortest supply) in estuarine areas, while phosphorus can induce eutrophication at very low concentrations in fresh waters.

Nitrogen concentrations in road runoff are variable. Values ranging from concentrations of 0-2 parts per million (= milligrams per liter or mg/L) to a load of 2.5 lbs/curb mile/year have been reported. Phosphorus levels reported are under 1 mg/L (0.07-0.79 mg/L), but are much higher than levels causing eutrophication (0.01-0.1 mg/L). Most phosphorus is bound up with particulate matter, and virtually all of it (up to 99% in some research) settles out with sediments. However, phosphorus may be re-released from the sediments and stimulate nuisance plant and algal growths under certain conditions.

Toxicity of Road Runoff

While road runoff contains many toxic constituents, not all are in a toxic form. Toxicity experiments have showed mixed results, but generally show significant stress to aquatic organisms.

In Rhode Island, the EPA is planning to conduct toxicity tests on runoff collected from storm basins discharging to the Pawtuxet River.

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Predicting Concentrations

Several methods have been developed to predict the concentrations of pollutants from road runoff in surface water.

The Nationwide Urban Runoff Program (NURP) study, published in 1983, compiled data from many studies across the country and produced coefficients for determining concentrations of several contaminants. While road runoff is not differentiated from other sources of urban runoff, the results are considered reliable estimators of runoff from urban land. A more recent study compiled the results of road runoff studies from across the country, determined the overall median value for each pollutant, and compared them to NURP results. These are listed below.

Highway runoff characteristics*

(median values, in mg/L)

	A. Shelley	B. NURP
Suspended solids	108	100
Chemical ox. demand	86	65
Kjeldahl nitrogen	2.18	0.68
Orthophosphate	0.35	0.33
Lead	0.31	0.14
Zinc	0.24	0.16

* Shelley, P.E. and D.R. Gaboury. 1986. Estimation of pollution from highway runoff - initial results. Pages 459-473 in B. Urbonas and L.A. Roesner, eds., *Urban runoff quality: impacts and quality enhancement technologies*. New York: ASCE.

What Towns Can Do

- Avoid curbed drainage wherever possible, as it facilitates runoff of untreated water to surface water bodies.
- Any measures reducing traffic volume or road dimensions are useful (for instance, cluster development minimizes road length and the distance each driver has to travel, reducing the effective volume).
- Removing sediments from roads can remove the bulk of the pollutant load as well, depending on the efficiency of sediment removal. Vacuuming is much more efficient than sweeping.
- Detention/retention ponds remove most sediments, metals, and phosphorus from runoff. On-site infiltration helps recharge groundwater and reduce peak flood levels; soils may additionally remove part of the pollutant load.

THE LAND MANAGEMENT PROJECT

Commercial Land Use

Fact Sheet No. 5 • September 1989

Commercial land use includes the parking lots, buildings and related structures of non-industrial business areas - malls, stores, commercial strips, and associated parking lots and access roads. Commercial developments create large impervious surfaces which alter watershed hydrology, increasing runoff rates and downstream flooding. Heavy metals, hydrocarbons, and solids, mostly from vehicles or related maintenance, collect on the impervious surfaces and run off with stormwater, threatening receiving water quality.

Key Findings

• The hydrologic modifications created by impervious land increase peak flood levels, reduce infiltration and groundwater recharge, and reduce stream base flow levels.

• The primary factor influencing potential pollution and hydrologic problems is the amount of impervious area.

• In New Hampshire, several heavy metals frequently exceeded EPA toxicity criteria in undiluted parking lot runoff.

Hydrologic Modifications

Impervious surfaces are by definition impermeable to water. During storm events, all of the water falling on impervious surfaces rapidly runs off into receiving waters. As reported by Schueler (1987) and others, this has several effects:

• Increased peak flood discharge, up to two to five times pre-development levels.
• Increased storm runoff volume (about 50% more in a moderately developed watershed compared to a forested watershed).
• Decreased time for runoff to reach receiving waters (up to 50% faster has been reported).
• Higher frequency and severity of flooding.
• Enhanced runoff volume and velocity gives runoff water greater energy to erode land and carry sediments downstream to receiving waters.
• When less water infiltrates and recharges the groundwater, water tables fall and there is less dilution of groundwater pollutant concentrations. Stream baseflow (the flow derived solely from groundwater discharge, during dry periods) also drops.
• The temperature of runoff over unshaded impervious land is increased, affecting coldwater stream habitats. Streams in Vermont and elsewhere have been subject to such thermal alterations.

Methods are available for the calculation of runoff rate and volume and flooding frequencies, given watershed characteristics. Runoff coefficients available from the Soil Conservation Service indicate how much of rain volume falling on different types of surfaces becomes runoff. Runoff is directly correlated with percent imperviousness.

Water Quality

Most of the pollution from commercial land use relates to vehicle use. Heavy metals and hydrocarbons derive directly from vehicles, and sand and salt come from pavement de-icing. Additional sediments come from erosion around the impervious areas. The pollutants are transported via runoff into surface waters or into the soil and groundwater. Much of the pollutant load is bound up with suspended particulates.

Hydrocarbons

Hydrocarbons in runoff derive mainly from engine oil, and either float on the surface or settle with sediments. Research on a 31-acre commercial area in Rhode Island found the total hydrocarbon load to be roughly 5.2 pounds per acre per year. The study further concluded that 83-93% of hydrocarbons were bound up with particulate matter, and that 64% in the "first flush" of runoff (the first pulse of runoff containing the bulk of the concentration of pollutants) were in settleable solids. In either case they can adversely affect aquatic organisms (via toxicity or physical obstruction such as coating). The persistence of hydrocarbons is variable. Some evaporate rapidly, while others persist for many years, usually in sediments.

Summary of Contaminants and Concerns

Hydrocarbons - Often at levels toxic to aquatic life; may persist in sediments for substantial periods; variable behavior and toxicity.

Heavy metals - Often reach levels toxic to aquatic life; may pose drinking water threat.

Solids - Transport medium for other pollutants; alters habitats, chokes or smothers aquatic life.

Sodium, chloride - Highly soluble and persistent; often exceeds standards and recommended levels in surface waters and groundwater.

Oxygen-demanding material - Reduces oxygen levels in surface waters.

Nutrients - Stimulate excessive plant growth.

Heavy metals

Metals are derived primarily from vehicles, through general wear and as by-products of combustion. Metals may occur in dissolved or particulate form, though the majority are found in particulate form. Most metals have high potential toxicity and may be taken up by organisms, where they enter the food chain. Metals may also be adsorbed to soil particles or settle out with sediments.

High concentrations of metals occur in runoff from such commercial areas as parking lots and automotive yards. A New Hampshire study of a parking lot found zinc, lead, copper and cadmium in undiluted runoff to frequently exceed EPA toxicity criteria.

Solids

Suspended and settleable solids are a transport mechanism for other pollutants, and can directly degrade surface water quality as well. Suspended solids reduce light penetration and therefore reduce photosynthesis. They can clog or otherwise stress aquatic organisms, and can alter the substrate or bury organisms. Removing most of the sediment load, in a settling pond for instance, also removes most of the contaminant load.

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Sodium and chlorides

Sodium and chlorides in commercial runoff derive from de-icing. Runoff from a 35-acre shopping center and parking lot on Long Island yielded median sodium concentrations of 40 mg/L, well over the 20 mg/L level some states have adopted as a drinking water standard. Chloride levels likewise were often high (median of 71.5 mg/L). More importantly, concentrations of both contaminants in groundwater were high, suggesting most of the sodium and chloride load reaches the groundwater with little attenuation.

Oxygen-demanding material

Biological or chemical oxygen demand (BOD or COD) are measures of how much oxygen may be consumed by the presence of contaminants. This usually involves organic matter, such as vegetation or animal waste, being broken down by oxygen-consuming bacteria. Oxygen levels of receiving waters are reduced. Organic matter often contributes to eutrophication as well, serving as a source of nutrients.

Nutrients

Nutrients (nitrogen and phosphorus) may occur in commercial runoff where there is input from fertilized land or where there is some accumulation of waste. The primary impact is to stimulate plant growth, which may lead to eutrophication. Phosphorus has the greatest impact on fresh waters, while nitrogen is the limiting nutrient in coastal waters.

What Towns Can Do

The primary factor influencing potential pollution from commercial land use is the amount of impervious surface. This determines the quantity of runoff generated and, in general, the available pollutant load. Traffic volume, surrounding land use, and maintenance are also important.

To reduce the impact of commercial developments, several measures should be considered:

- Limit impervious area wherever possible.
- Siting: Avoid sensitive areas, such as groundwater aquifer recharge areas or secondary recharge zones, impermeable soils, or sensitive surface waters.
- Drainage: Design drainage so that as much runoff as possible infiltrates on site. This can be achieved by directing runoff to buffer strips, vegetated islands or infiltration basins, and by using permeable pavement. Catch basins, detention/retention ponds, vegetated swales, and other structures may be appropriate. Oil-water separators may be used in catch basins, if maintenance can be assured.
- Maintenance: Since most of the pollutant load is bound up with solids, sweeping can remove some contaminants bound to particulates, though vacuuming has been found to be much more effective than sweeping. Surfaces should also be kept free of trash, leaks, etc.

THE LAND MANAGEMENT PROJECT

Stormwater and Wetlands

Fact Sheet No. 6 • September 1990

The Problem

Development alters the hydrology of watersheds, changing natural storage and drainage patterns and encroaching on sensitive areas. As more roads, parking lots, and other impervious areas are developed, more pollutant-laden stormwater collects in man-made conveyances, from which it is often rapidly discharged to wetlands and other receiving waters.

Wetlands are natural pollutant filters, retaining or dispersing many of the pollutants that are brought in by stormwater runoff. Because of their pollutant treatment capabilities, increasing attention is being given to creating wetlands for treatment of contaminated stormwater and wastewater. But it is also important to consider how stormwater quality affects both "created" and natural wetlands. Stormwater runoff, typically containing sediments, hydrocarbons, nutrients, and other contaminants, is frequently discharged directly into wetlands and water bodies. The complex chemistry and biology of different wetland types can make them vulnerable to runoff constituents in varying degrees.

Key Findings

- **Stormwater-borne sediments may alter the substrate, stress organisms, and lower water depths, thus altering the vegetation and reducing the storage volume of a wetland. Sediments also carry pollutants, such as heavy metals and hydrocarbons.**

- **Because nutrients such as nitrate and phosphorus stimulate excessive plant growth, they are a concern in marshes, ponds, and bogs.**

- **Metals accumulate in wetland sediments and may affect some wetland organisms; their long-term impact is poorly understood.**

- **Best management practices (BMPs) can be very effective at pre-treating stormwater runoff before it enters a wetland.**

Wetlands include a wide range of habitat types. They may be salty, or fresh, and may have shallow or deep water, mineral or organic soil, and dense or sparse vegetation. In addition to swamps, bogs, and marshes, the R.I. Fresh Water Wetlands Act includes rivers and ponds in its wetland definition. These diverse ecosystems interact with nutrients and other water-borne contaminants in many ways. The most important factors in pollutant storage and treatment are hydrology, vegetation, and soils.

Key Factors

Hydrology

In Rhode Island, wetlands usually occur at naturally low areas in the landscape that intersect groundwater levels, i.e. they are groundwater discharge sites. Wetlands may also receive input from surface water streams or from overland runoff. Most wetlands release water directly into a water body such as a stream or lake, and so are intimately connected with surface waters. If water flows rapidly through a wetland, there will be little time for settling or processing of pollutants; as a result, the pollutants will have less impact on the wetland and more impact on downstream waters. If wetlands are shallow and heavily vegetated, flow may be very gradual, accomodating different physical, chemical, and biological effects.

Vegetation

Dense vegetation provides more biological activity to process pollutants and more efficiently traps sediments. Open-water wetlands lack this natural filtration process and may be more strongly impacted by pollutants - particularly nutrients such as nitrogen and phosphorus, which can stimulate excessive plant growth or "eutrophication."

Soils

Soil traps fine sediments and serves as a substrate for the chemical attraction and attachment (adsorption) of pollutants. If stormwater entering a wetland seeps into the soil layer as it flows through, the contaminants will likely be retained and accumulate in the soil. However, some pollutants (e.g., nutrients and pathogens) are less likely to accumulate over long periods in wetland soils.

Stormwater Impacts on Wetlands

Pollutants in stormwater affect wetlands and water bodies in many different ways. Certain pollutants settle out and accumulate in bottom sediments, some are broken down or destroyed, and still others are converted to harmless gasses and evaporate into the air.

Sediment deposition is significantly higher in wetlands receiving urban runoff than in unaffected wetlands. Sediments alter the substrate, stress aquatic organisms, and reduce light penetration (which inhibits photosynthesis). Heavy sedimentation changes the water depth and thus alters both the hydrologic regime and the plant community of a wetland. Sediments also carry other pollutants, particularly heavy metals and oils, that may be attached to the particles.

Hydrologic modification (e.g. grading, installing pavement and other impervious surfaces) inhibits groundwater recharge and increases the volume and rate of surface runoff. When less water discharges gradually from the groundwater or more water enters the wetland in large pulses of stormwater, runoff magnitudes will fluctuate and water levels in wetlands or receiving waters will vary widely. This alternate flooding and drying affects the types of vegetation and other organisms that can survive in a wetland. Moreover, coastal wetlands can be greatly affected by changes in salinity. Increased freshwater inputs can cause drastic and often undesirable changes in salt marsh vegetation.

Nutrients (nitrogen in salt water, phosphorus in fresh water) stimulate excessive plant growth. In a densely-vegetated wetland, plant materials take up "excess" enrichment, and nutrients will have little impact. In other wetland types (e.g. sparsely vegetated marshes or shallow ponds), nutrients may cause significant shifts in the vegetation. Nutrient-poor wetlands, mainly fens and bogs, will be greatly altered by nutrient enrichment.

Metals accumulate in sediments or are taken up by plants. Studies of sewage sludge in salt marshes have found metals in virtually all components of ecosystems: soils, water, plants, and organisms. If dissolved oxygen levels fall below certain levels (anoxia), metals may be re-released to the water column. Low dissolved oxygen levels frequently occur in eutrophic systems when vegetation decays (see **Oxygen demand**, below).

Hydrocarbons accumulate in the sediments of receiving taken up by shellfish and filter feeders.

Pathogens, or disease-causing bacteria and viruses, are much more abundant in wetlands receiving urban runoff. Although they may have little direct effect on wetlands, pathogens are a concern if the wetland or adjacent waters are used for recreation or for drinking water supply.

Oxygen demand, either biological (BOD) or chemical (COD), is the reduction of oxygen level associated with the breakdown or consumption of organic material. Oxygen depletion can make a habitat unsuitable for beneficial aquatic organisms, sometimes leading to fish kills, and can cause the release of metals and phosphorus from sediments. Oxygen demand has little effect on vegetated wetlands but can strongly affect open wetlands and water bodies.

Organic chemicals are extremely diverse, making it impossible to generalize about their behavior in wetlands or their potential impacts. However, many organic compounds are extremely persistent, and have been shown to have adverse impacts on crab and insect populations in salt marshes. Some organic chemicals bioconcentrate in the food chain.

Thermal pollution occurs when runoff flows over a warm, exposed surface, such as a large parking lot, and into a water body. The artificially warmed water raises the temperature of the receiving water body and affects the aquatic organisms living there. Many organisms, including valuable fish species such as trout, have very low tolerances for temperature increases.

How Effects of Stormwater Can Be Avoided

Since one of the biggest problems associated with stormwater runoff is sediment and associated contaminants (such as metals), sedimentation or presettling basins are a simple and effective mechanism to prevent pollution. Wet **retention basins** and **extended detention basins** are particularly effective in removing sediments and associated pollutants via settling. Where aquatic plants are successfully established, nutrients can also be taken up, though plants must be harvested regularly to ensure removal of the nutrients from the system. When properly designed and installed, infiltration practices such as **buffers, swales, infiltration trenches**, and **galleys** can also be effective in filtering out sediments and other pollutants before they enter a wetland or water body. The overall effectiveness of best management practices can be increased when they are used together in series.

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Biological Mosquito Control

Fact Sheet No. 7 • September 1990

The Problem

Untreated, stormwater runoff can pollute receiving waters and cause flooding hazards. Effective means of regulating this runoff are the use of detention, retention, and infiltration basins. Well-designed stormwater management structures eliminate conditions that promote mosquito breeding. Initial approaches include:

- **Ponds/created wetlands with at least 50% open water promote water movement and create suitable environments for mosquito predators.**
- **Ponds/created wetlands should be deep enough to support fish predators.**
- **In extended detention ponds and infiltration basins, pervious low-flow channels should be installed to allow complete drying in order to alleviate standing water problems and to prevent erosion.**
- **The provision of steeply sloping sides allows predators access to mosquito larvae habitats.**

Key Findings

- **Proper design and management practices can largely prevent mosquito breeding problems in stormwater BMPs.**
- **Non-chemical means of mosquito control are very effective and widely available.**
- **The use of chemical pesticides creates insect resistance, necessitates higher doses, enhances contamination potential, and can be more costly than biocontrol.**
- **The application of biocontrols requires detailed biological information and expertise.**
- **Research and practical experience have shown that programs that combine different methods of biocontrol have higher success rates.**
- **The state of Rhode Island provides funding to communities that wish to participate in a mosquito abatement program.**

Control of Mosquitoes

As early as 1889, the use of biocontrols (natural enemies) to combat insects was introduced into the U.S. Simultaneously, the first widely-used pesticide was introduced (Paris green or acetoarsenite). In addition, kerosene was used as a larvicidal oil (a thin film of oil spread on the surface of a waterbody preventing mosquito larvae from attaching to surface tension in order to feed). Paris green, kerosene, and swampland ditching and draining were the mainstays of mosquito control until DDT came into use in 1939. Biocontrol measures were increasingly neglected as DDT, which was cheap and effective, came into wide-spread use.

By the early 1960's, studies showed that DDT had adverse effects on wildlife and human health and was persistent in the environment. Heightened insect resistance to DDT required that increasing amounts be used (insect adaptability causes chemical means of control to be short-lived). In addition, DDT killed not only the targeted insect but also its predators, resulting in a resurgence of the pest in greater numbers during the temporary suppression of its natural enemies. The need for less-damaging and longer-lasting means of control became apparent.

Over the last two decades, new non-pesticidal forms of mosquito control have been developed that take advantage of biological factors that can reduce and regulate mosquito populations. These approaches include the use of bacteria, natural enemies, oil films, insect growth regulators, the release of sterile males and chemosterilization, and rotational impoundment practices (which regulate seasonal water flows and depths).

By incorporating these new practices into the regular maintenance programs that stormwater basins require, managers can effectively address mosquito control needs. Some training may be required in order to ensure that control methods are applied at optimum times (specific to stages of insect development).

New Methodologies

- **Bacterial means of control** rely on mosquitoes ingesting bacteria that act as toxins within the digestive system. Now widely available and used, the most common bacterial agent is B.t.i. (*Bacillus thuringiensis* var. *israelensis*), which is available in either liquid, granular, or briquette form. Studies have shown that B.t.i. becomes more effective as the temperature and pH of a waterbody increases, so applications should be specifically timed.

- **Natural enemies** of the mosquito include certain fish, bird, mammal, and insect species. These predators can be introduced in small numbers to reproduce and maintain their populations within the habitat, or they can be released repeatedly in overwhelming numbers to control mosquito larvae. Fish that eat mosquito larvae (e.g. mosquito fish, guppies) are used in Essex County, MA to control mosquito larvae in coastal marsh areas. The control program consists of digging small channels to connect pools and basins, thus providing the fish access to breeding areas. According to the program director, environmental impacts have been minimal and tests have shown a 90% decrease in mosquito activity in the treated areas.

- **Oil Films** limit larval feeding by breaking water surface tension. Modern oils are made from plant derivatives which do not alter water chemical processes or gas exchanges. One invisible commercially available oil film, "Arosurf," is one molecule thick, and has rapid spreading capabilities. Although oil films are more expensive than other biocontrols, their use in stormwater basins would require small, specifically applied releases which could be highly effective.

- **Insect growth regulators** (IGRs) are synthetic hormones that prevent larvae from reaching the adult stage. Methoprene is a widely-used IGR that is sold under the name "Altosid." These hormones are specific to orders of insects and sometimes specific to species. Application of IGRs must be timed carefully to coincide with stages of insect development. An advantage to IGRs is that there are no ill effects on non-targeted organisms.

- **Sterilized release methods** use sterile male mosquitoes to compete with fertile males for mating privileges. This can lower mosquito birth rates. However, it is difficult to mass-rear sufficient quantities of sterile males to be truly effective. **Chemosterilization** methods use chemicals to cause sterility in mosquitoes. The chemical nature of this method means that it is susceptible to insect resistance.

- **A rotational impoundment management method** retains natural resource benefits. This method is used in coastal areas where dikes and impoundments were constructed before wetlands protection acts were in existence. This method seasonally reconnects estuary waters with impounded areas of marsh. This practice maintains high non-fluctuating water levels within breeding areas in order to inhibit egg-hatching.

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Mosquito breeding is stimulated by:
- alternating wet and dry conditions
- low dissolved oxygen levels in water
- presence of decaying organic material
- stagnant water

Mosquito breeding is limited by:
- consistently wet or dry conditions
- high dissolved oxygen levels in water
- moving water
- lack of food source (organic material)

COST-EFFECTIVENESS

Biocontrols are often cost-effective because they require fewer follow-up treatments. While chemical controls, require progressively higher investments, biocontrols often involve **decreasing** costs. Manufacturers see a decrease in potential profit and are thus less motivated to promote biocontrol methods. Fortunately, mosquito control agencies have created a demand for these products and industry has responded. The bacteria, insect growth regulators, and oil films previously mentioned in this fact sheet are available from the manufacturers or through private contractors. Some communities jointly purchase pesticides in order to obtain a volume price. Many of these methods are *in use in Rhode Island and throughout New England.*

Can Biocontrols Work For Your Community?

Advantages and constraints must be examined in order to determine applicability.

Advantages:
- Biocontrols are generally specific to the targeted pest.
- The methods are generally non-polluting.
- Biocontrols do not induce resistance.
- The controls can be self-perpetuating.

Constraints:
- Biocontrols require a considerable amount of expense and work for single-species control.
- Application of biocontrols requires detailed information and expertise.
- These methods do not result in immediate or dramatic kills (which may be desirable in case of epidemic).
- It is difficult to predict the performance of natural predators.
- Weather conditions can affect some biocontrols.

In Rhode Island, communities with mosquito problems can take advantage of a state-wide mosquito abatement program. Twelve communities are presently enrolled. Communities design specific programs utilizing state-registered pesticides. These programs must then be approved by the state Mosquito Abatement Board (phone 277-6151). Communities can obtain state grant funding for participation in this program.

This fact sheet does not constitute a Land Management Project endorsement of these methods. The LMP provides this information in an effort to promote awareness of the options available to communities.

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THE LAND MANAGEMENT PROJECT

Subdivision Regulations

Fact Sheet No. 8 • March 1991

Subdivision Regulation

Public bodies control the platting and conversion of undeveloped land, through subdivision regulation, into building lots. The regulations are designed to provide for orderly growth and co-ordinated development. A developer is required to meet certain conditions in exchange for the privilege of recording a plat. Public control of this process is justified because of the potential impact the subdivision can have on a community's natural, cultural, and economic resources.

A basic function of subdivision regulations is to prevent haphazard development, that will have a negative impact on the community. A broader application of these regulations is to guide land-use to land suitable for development. They can be one element of land use controls that include zoning regulations and comprehensive plans that prescribe land uses for developed and undeveloped land.

Key Findings

- **Construction of both frontage lot and large-scale subdivisions set community development patterns that are extremely difficult to alter.**

- **Long-term effects of haphazard subdivision on neighborhoods include: lower quality of life; traffic congestion; "sprawl"; strain on public facilities; destruction of natural resources; and an increased tax burden.**

- **Legal lot definition avoids boundary disputes and title defects.**

- **Performance bonding ensures that subdivisions will be built to the stated community standards.**

History of Subdivision Regulations

The orderly division of land into parcels is an activity that dates back to the ancient civilizations. The Egyptians, Greeks, and Romans all developed patterns for the laying out of towns. Buildings were oriented to capture breezes and for defense; sanitary sewers were provided; and recreational areas were designated.

American colonists brought village patterns from their homelands to this country. The Spanish, in particular, followed a system of land settlement and town planning that was formalized in written rules and regulations. Unified standards for Spanish settlements were codified in 1593 by King Philip II in the Laws of the Indies, which has been called America's first planning legislation. Plazas, roads, and farm areas were specifically sited. Later colonial regulations included street standards, lot layout, setbacks, and building specifications.

After the Revolutionary War, land in the public domain was offered for sale. The Continental Congress enacted the Land Ordinance of 1785, which contained regulations to guide the surveying and disposition of lands in the western territories. It established a rectangular system to survey townships and sections with a method still in use today.

Land speculation of the 1800's and the early 1900's has left much of the U.S. with a legacy of inappropriately sited communities and conflicting land uses. In 1928, the Federal Government enacted the Standard City Planning Enabling Act, which gave communities the power to shape growth. Emphasis was placed on requiring roadway and lot improvements for the subdivision in addition to providing a convenient identification method to reference when transferring lots.

The post-World War II development boom, fueled by federal housing policy and the desire of U.S. citizens to own a single family detached house on a large lot in the suburbs, brought with it greater acceptance of subdivision control. By 1952, all states, with the exception of Vermont, had adopted subdivision control enabling legislation. Regulations from this time period started to include provisions that required more of developers (road standards, water and sewer facilities, dedication of schools and parks). At the present time, developers are more likely to challenge restrictions because of spiraling subdivision costs. In constant dollars, land and subdivision costs have increased by almost 70% during the time period from the 1920's to the 1980's. These factors force a community to weigh the trade-offs between increased amenities and increased home ownership costs.

SUBDIVISION REGULATIONS GOVERN

Construction Standards
- Sewer, water, and utility lines
- Drainage system placement
- Grading and topography
- Roadway Construction
- Erosion Control

Site Layout
- Traffic circulation
- Street lighting
- Pedestrian and bicycle access
- Dedication of land for open space
- Building siting

Long Term Impacts
- Compatibility with surrounding areas
- Easements
- Bond requirements
- Ownership and maintenance of open space

Purpose

"...to prevent the overcrowding of land; to prevent the development of unsanitary areas for housing purposes; to secure a well articulated street and highway pattern; to promote coordinated development of unbuilt areas; to secure an appropriate allotment of land area in new developments for all the requirements of community life; to conserve natural beauty and other natural resources; to conform to any master plan that may have been adopted; and to facilitate the adequate, efficient and economic provision of transportation, water supply, sewerage, recreation, and other public utilities and requisites."

Source: *Town of North Kingstown, RI, Subdivision and Development Regulations.*

The subdivision regulations of North Kingstown, RI, in addition to the components mentioned above include soil based restrictions. This provides the Town the opportunity to direct growth onto the land that is most suitable for development. Soils where development is limited include: high watertables; coastal flooding areas; slowly permeable; extremely stony; subject to frost action; and steep slopes. This type of regulation can direct development to the soils that can accommodate growth, minimizing the impact on groundwater surface water. It can also reduce maintenance costs associated with misplaced roads, foundations, and septic systems.

The Land Management Project assists towns with growth management and water quality protection. For more information on this and other topics, contact the Land Management Project at 83 Park St., Providence RI, telephone 401-277-3434.

Subdivision Regulation Improvements

- Provide developers with a subdivision design criteria list. This will avoid surprises and ensure that developers have full knowledge of what the subdivision regulations require.

- Develop regulations that allow flexibility of design in order to preserve open space and reduce the "sprawl" character of a community. This helps avoid the row-after-row gridiron effect.

- Require that the natural terrain and soil conditions of a parcel to determine the suitability of a site and to set design constraints.

- Upgrade drainage requirements to promote the use of modern stormwater controls that are efficient and environmentally sound. Developers can be required to include in their plans grassed swales, detention and retention basins, infiltration devices, and sediment traps if applicable. One system can often serve a whole subdivision.

- Regulations that address the removal and replacement of natural vegetation can help reduce erosion, preserve habitats, and promote stormwater runoff control.

- Aside from reducing construction costs for developers, the promotion of cluster development reduces municipal costs for roads, drainage, and facilities maintenance. Other benefits include more open space, less stormwater runoff, and less air pollution from autos.

- Require that site designs take advantage of sun angles, prevailing winds, tree stands, hills, and other natural conditions that will save energy by reducing heating and cooling costs.

- Open space requirements for subdivisions can range from 10-50%. A percentage of 25-30% is considered achievable in most cases, depending on features of the land and on how your regulations address wetlands and buffer zones. Regulations should state that density allowance excludes wetlands, steep slopes.

- Co-ordinate your standards with the standards of neighboring communities. This avoids poor street alignment, blocked roadways, alternately wide and narrow streets, and pavement differences.

- Consider the use of impact fees to reduce the financial burden that a development can place on a community (presently used in Cranston, RI). These fees can be used to pay for expanded infrastructure, services, and schools necessitated by the new development.

THE LAND
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Zoning

Fact Sheet No. 9 • March 1991

The Problem

A municipal Planning Board/Commission is charged with the responsibility of providing for the orderly development of a community. Local government traditionally exerts its power to regulate land use through a zoning ordinance. The ordinance consists of a text defining zoning/land use categories and a zoning map showing the application of these categories to specific parcels of land. Zoning is key to *planned development* in a community and is a crude but comprehensive system of building control. It essentially provides a blueprint for development and shows what is "programmed" to happen (e.g. range of intensities and types of development), but it cannot induce development activity.

Because municipal facilities become stressed by rapid growth, communities need to continually update land use and building regulations in light of the best information available *to prevent the overcrowding of the land, establish acceptable standards of community development, and protect the town's natural features.*

Key findings

• Zoning is the embodiment of the comprehensive plan, the zoning scheme gives legal power to community decisions regarding open space, protection of character, and preservation of vital resources.

• In many R.I. communities, presently zoned uses are inconsistent with future need (i.e. industrial zones over aquifer recharge areas).

• Innovative techniques for the design and siting of residential development (e.g. Planned Unit Development) can preserve the aggregated total density of a development by clustering higher density development while preserving community open spaces.

• Zoning can have significant impacts on land values, though the direction and significance of the impacts depend on how well zoning is administered and on the supply and demand situations in the land market.

• A municipal Zoning Board of Review plays a key role in determining exceptions and variances to the planned zoning scheme and can significantly impact the character of the community.

Components of a Zoning Ordinance

Site layout requirements.
These may include, among other things, minimum lot area, frontage length and depth, minimum distance from structure to front, side, or rear lot line (setbacks), maximum percentage of a site which may be covered by a structure, placement of driveways or curb cuts, parking requirements, screening requirements, and limits on the size or placement of signs.

Dimensional Restrictions
These may include maximum allowable height of structures, maximum number of stories and maximum floor area of structures. The latter is often cast in terms of floor area ratio (FAR), which indicates maximum permissible ratio of floor area to site area.

Appropriate land uses.
In a residential zone, the ordinance may specify that dwellings must be occupied only by single families, may define what constitutes a family and may enumerate certain non-residential uses permitted in the zone. In commercial and industrial zones, the ordinances will generally specify which uses are permitted and which are not.

Procedural matters.
The ordinance should specify how it is to be determined whether building plans are in conformity to the zoning ordinance. The ordinance should also specify an appeal procedure by which an applicant can apply for relief. In many communities, the initial appeal authority is vested in a special body generally referred to as the Zoning Board of Appeals.

Environmentally Sensitive Zoning

Cluster or open space zoning

Cluster ordinances generally permit the building of houses on smaller lots than otherwise required, provided that the space "saved" is used for community purposes and/or linked for habitat vale. Cluster zoning permits the preservation of substantial blocks of open space and reduces development costs in a number of ways. Placing houses closer together reduces the amount of road surface, curbing, and utility line required per house, reducing preparation costs.

Cluster developments do generally result in lower nonpoint pollution loadings than more conventional land use planning approaches for the same number of units. While not a substitute for public acquisition of open space, "open space zoning" protects sensitive areas by restricting development.

Performance standards

Local performance standards (often beyond state minimums) stipulate what may or may not be done in terms of end results instead of giving detailed regulations upon the exact form of development. Examples of types of standards include: percent of pervious and impervious cover allowed on a site, landscaping, drainage standards (e.g. zero net runoff), and other design and engineering minimums. Performance standards may be included in a site plan review or cluster provision or may stand alone in the text of the ordinance.

Overlay Zones

Overlay districts protecting sensitive resources (such as groundwater aquifers, wetlands, floodplains and watersheds) are becoming an increasingly common zoning practice in Rhode Island cities and towns. Overlays are superimposed on existing zoning districts and impose specified requirements (e.g. density restrictions, septic systems restrictions) in addition to those otherwise applicable for the underlying zone. Such zones should explicitly define the purposes of the overlay in protecting resources, should define permitted and prohibited uses, and the penalties of non-compliance.

Incentive Zoning

With flexible land use intensities, a local board may wish to offer a developer incentives to provide increased density or other bonuses in exchange for providing special public benefit or amenity. Development incentives for increased open space, additional housing choices, and public facilities may result from flexible intensities of land use.

The Land Management Project assists towns in water quality protection and related issues. For more information on this and other topics, contact the Land Management Project at 83 Park Street, Providence 02903, or telephone (401) 277-3434.

How Zoning Can Protect Water Quality

- *use restrictions* - Prohibits or restricts location of polluting resources within the zone.
- *density restrictions* - Allows development only in sufficient densities to avoid exceeding the assimilative or filtrative capacity of the soil.
- *lot surface restrictions, setbacks* - Limits the conversion of natural to impervious surfaces, preserving the natural storge capacity, buffering water resources.
- *overlay zone* - Defines boundaries of irregularly shaped aquifers and watersheds.

Planning

Professional planning and development staff.

Planners are trained to provide technical assistance to local land use boards and to review development plans as well as training in the preparation of land use regulations and comprehensive community plans. Planners help boards and commissions make responsible decisions concerning effects of land use on water quality, local fiscal conditions, etc.

Towns should act to avoid interim development controls by actively planning and making zoning decisions that are in conformance with the adopted comprehensive community plan. The Rhode Island Comprehensive Planning and Land Use Regulation Act (R.I.G.L. 45-22.2) requires that communities amend their zoning ordinances in order to comply with the goals of the comprehensive plan; re-zoning is an integral part of the comprehensive planning process.

Technical assistance.

Model zoning ordinances and scientific literature related to growth management and water quality protection techniques have been assembled and reviewed by the Land Management Project (LMP). In addition, LMP offers general advice and technical assistance for communities in evaluating the impacts of their land use decisions. For example, see LMP's *Preparing a preliminary build-out scenario for your community: A guide for Citizens Advisory Committees.*

Other pertinent sources include:

- *Growth Management Workbook* (Pioneer Valley Planning Commission and the MA Executive Office of Communities and Development, 1988) and

- *Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators* (Planning Advisory Service, 1975).

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THE LAND MANAGEMENT PROJECT

Site Plan Review

Fact Sheet No. 10 • March 1991

The Problem

Often conventional zoning and subdivision regulations do not address the environmental, economic and aesthetic needs of a community. A Site Plan Review (SPR) provision in a community's development ordinance provides the opportunity to comprehensively assess the impacts of a development proposal and to consistently produce environmentally sound designs. Under standard regulations, there may be considerable potential to permit development that fails to consider area-wide management needs or to embody the principles of "sustainable development". Watersheds may be developed beyond the capabilities of the land to accommodate growth and attenuate pollutants. Similarly, site designs may ignore important opportunities to "retrofit" stormwater facilities for improved water quality. Finally, a void may exist between the planning process and construction activities that results in development that does not resemble what was originally approved.

Key Findings

• When planners and developers can reach a consensus on what is expected of a development proposal, a town can be more confident that the final project will resemble the approved plan.

• Because of its comprehensive nature and flexibility, Site Plan Review strengthens the planning process by filling the voids left by ordinary subdivision and zoning regulations. SPR can jointly address environmental, economic and aesthetic concerns.

• SPR can give a community authority to review the environmental impacts of proposals that do not require DEM Wetlands or CRMC permits, among others. SPR can focus on: landscaping, cultural and historical resources, traffic, sensitive areas, stormwater, and other elements, thereby ensuring consistency with the community's comprehensive planning goals.

Basic Provisions

Site Plan Review is a systematic process to review and permit development that is beneficial to a community, while mitigating its negative impacts. The process involves analyzing specific plan elements in detail and simultaneously evaluating the cumulative impacts the development will have on the community.

In Rhode Island, a community's authority to impose zoning restrictions is established by the Rhode Island Zoning Enabling Act. This legislation provides the power and legal basis for implementing a Site Plan Review provision in a community's development regulations. SPR references other stated town standards. The purposes of the provision and the established standards should be clearly stated (both generally and specifically) for each element considered in the review process.

By making requirements fairly definite, the developer can incorporate them into initial planning and budgeting, minimizing the potential for cost over-runs and for diversions from the approved plans.

Because the site plan review process is a comprehensive tool it is very important to ensure that all elements are reviewed by the proper town professionals. For example, (drainage) stormwater management plans should be reviewed by engineers, planners, and environmental coordinators. All involved parties should understand the purposes of the SPR process. Communities can develop checklists for each of the elements they wish to consider in their own SPR provision. Elements commonly considered include:

- **Environmental Constraints**
- **Construction Sequence**
- **Economic Impact**
- **Access/Parking**
- **Land Use Compatibility**
- **Aesthetics**
- **Landscaping**
- **Impervious Area**
- **Drainage/Runoff**
- **Traffic Generation**
- **Signage**
- **Erosion Control**

Many communities may need to incorporate additional elements to account for conditions that are unique to the municipality.

Decision Making Process

The Site Plan Review process is divided into three basic phases: "pre-application", "application" and "review". In the pre-application phase, different scenarios are evaluated generally to determine what concept is workable. In the application stage, the overall concept is presented, and details of the proposal are worked out to satisfy the requirements of the provision. When the application is complete, it is subjected to a final review to ensure that all proposal elements are consistent, and that the development will not be detrimental to community interests.

Water Quality

The Site Plan Review process is an important tool that can be used to prevent pollution and to enhance the quality of a community's surface and groundwater resources. By limiting the amount of impervious area within a development, the quality and quantity of contaminated runoff leaving a site can be controlled at the source. The ordinance can require that Best Management Practices (BMPs) be installed to mitigate the impact of unavoidable runoff from a development project both during and after the construction phase. Standards as to the types of turf and plantings used can enhance a site's attractiveness, while lessening the site's need for water, fertilizers, pesticides, minimizing leaching.

The flexibility of SPR provides the planner and developer the opportunity to select which type of BMP is best suited for the specific conditions of the site and to fully integrate BMPs into the landscape design. For example, impervious parking areas may be reduced to control runoff generated. To control nutrients, landscaped portions of a site may be complemented with - areas left wooded (or in natural vegetation). Other landscaping controls required by SPR can serve both aesthetic and environmental concerns minimizing the impact of development through planning. Buffers can be constructed to screen parking from view, or circulation patterns that reduce auto trips.

Purposes of Site Plan Review

- Balance development and land protection goals; ensure orderly growth; supplement and facilitate implementation of the community's comprehensive plan provisions.
- Integrate land use controls to better protect the public health, safety, and general welfare while allowing for cost-saving efficiencies.
- Enhance enforcement capabilities, increasing the likelihood of a development resembling permitted specifications.

What Towns Can Do

- Identify natural features and their inter-relationships. Determine what values and functions of natural systems and landscapes pose necessary constraints on development.

- Establish a clear vision of the desired results of development within the community. What values help create your town's identity?

- Determine the size and type of development that will "trigger" Site Plan Review (number of parking spaces, type of permit, critical area, etc.), and what standards will apply for specific land uses.

- Set up a separate Site Plan Review ordinance; incorporate a Site Plan Review provision into existing zoning ordinance; or if necessary initiate the Site Plan Review as a special exception in the existing zoning process.

- Institute requirements that must be complied with in a detailed checklist format to determine an application's completeness before it enters the site plan review process.

Reference List

The following literature resources provide information on various aspects of Site Plan Review-- protecting landscapes; designing the decision making process; using model ordinances; setting standards for review of various specialized elements.

- *A Unified Development Ordinance*, Michael B. Brough, APA 1985, order from American Planning Association, (312)955-9100.

- *The Aesthetics of Parking*, Thomas Smith, APA PAS Report #411, 1988, $20 -- (312)955-9100.

- *Designing Urban Corridors*, Kirk R. Bishop, APA PAS Report #418, 1989, $20 --(312)955-9100.

- *The Subdivision and Site Plan Handbook*, Listokin and Walker, CUPR Books, $45 --(201)932-3101.

- *Site Plan Review: A Guide to Evaluating Natural Resource Capacity for Development*, Natural Resources Center, Connecticut Dept. of Environmental Protection -- (203) 566-3540.

The Land Management Project assists towns on water quality issues. for more information on this and other topics contact us at 83 Park St., Providence, RI 02903, telephone (401)277-3434.

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Stormwater Best Management Practices

THE LAND MANAGEMENT PROJECT

BMP Fact Sheet No. 1 • September 1990

The Problem

Stormwater runoff is simply the water that results from and occurs after a rainfall event. Stormwater becomes a management problem when natural lands are converted to other land uses, especially those involving paving or use of fertilizers and pesticides. Rainfall washes pollutants from impervious surfaces directly to water resources and causes chemicals to "leach" from turf.

"Natural" engineering techniques or Best Management Practices (BMPs) should be used to preserve and enhance the natural features and pollutant "treatment" processes of a site. The volume, rate, timing, and pollutant load of stormwater after development should closely approximate the conditions which occurred before development. A comprehensive stormwater management system provides flood protection, water quality protection, and erosion and sedimentation control. It is much easier and less expensive to prevent stormwater management problems through sound site planning and design than to correct them.

Key Findings:

• The pollutant removal capability of a BMP is primarily governed by three interrelated factors: the removal mechanisms used, the fraction of the annual runoff volume that is effectively treated, and the nature of the urban pollutant being removed.

• As a result of thoughtful design, regular maintenance, and creative landscape planting, environmental and human amenities can be provided by BMPs.

• Developing areas offer the greatest potential for utilizing a full range of structural and non-structural BMPs, and provide the opportunity to reduce more future pollutant loadings for less cost.

• BMPs are designed to address site-specific problems, but often work best in a series, as part of a coordinated watershed master plan.

BMPs

Best Management Practices (BMPs) are nonstructural and low-structural practices or combinations of practices that are determined to be the most effective, practical means of preventing or reducing pollution inputs from nonpoint sources (e.g. stormwater runoff, pesticide and nutrient leaching, and construction and development practices) in order to achieve water quality goals. Improving quality and controlling the quantity of runoff to receiving groundwater and surface water is a common purpose among these primarily preventative practices.

BMPs are often "peak-shaving" devices, that is, they control post-development peak floodwater discharge rates to pre-development levels be providing temporary detention/storage time. To treat pollutants, BMPs can operate to infiltrate water, can allow sediment to settle out or can accommodate plant uptake or chemical transformation. The selection of BMPs should be based on: type of land use activity, physical conditions in the watershed, pollutants to be controlled, and site-specific conditions.

Types of BMPs

structural - practices that are aimed at controlling the volume and discharge rate of runoff from urban areas, as well as reducing the magnitude of pollutants in the discharge water. Examples include: wet basins, extended detention wet and dry basins, artificial wetlands, infiltration devices, sediment basins, swales, buffers, and pervious pavement.

nonstructural - measures which minimize the accumulation of pollutants on the land surface and in the atmosphere during periods when rainstorms are not occurring (reduction before transport in stormwater). Examples include: land use and site planning techniques, protection of natural buffer areas, fertilizer management, cleaning catch basins, vacuum street sweeping, and other "good housekeeping" techniques.

erosion and sediment controls - practices that can be used to prevent transport of eroded material or soil in runoff, particularly from construction and other land disturbing activities. Examples include: road stabilization, sediment barriers, sediment traps and basins, and temporary vegetation. Cost-effectiveness for such practices is often measured in cost per ton of reduced soil erosion.

Definitions

retention - the holding of runoff in a basin without release except by means of evaporation, infiltration and emergency bypass. Physical, chemical and biological treatment processes can take place in the permanent pool.

detention - the temporary storage of storm runoff in a BMP in order to control the peak discharge rates, and to provide gravity settling of pollutants.

infiltration - the downward movement of water from the surface to the subsoil (expressed as inches/hour). Infiltration reduces the volume of rainwater discharged as runoff and allows for treatment within the soil.

detention time - the amount of time a parcel of water actually is present in a BMP. Hours can vary from 6 to 60, depending upon flood protection and water quality goals.

first flush - the runoff delivered to water courses during the earliest part of a storm. This runoff carries roughly 90% of all stormwater-borne pollutants. Often, BMPs are designed to hold this "first flush" for treatment.

Design Considerations

- pollutant removal efficiency
- site conditions
- cost effectiveness
- public safety
- aesthetics
- ease of maintenance (access)
- surrounding land uses
- available land area
- effectiveness in series
- depth to groundwater
- slope/soil conditions (e.g. infiltration rate, organic content)
- proximity to sensitive resources
- wildlife habitat

Maintenance

Like other pollution control devices, BMPs can only continue to be effective if they are installed properly, and regularly inspected and maintained. Maintenance tasks for most BMPs include both low-cost routine tasks, such as mowing and trash removal, and more expensive non-routine tasks, such as rehabilitation or sediment removal. Maintenance costs for BMPs can be significant. For example, capital costs for most structural flood storage devices range from $100 to $1000 per acre served and annual operation and maintenance costs range from $10 to $125 per acre served, depending on site conditions (EPA, 1988).

In most cases, the maintenance burden of a BMP depends primarily on the initial design and construction of the facility (Schueler, 1987). If maintenance requirements are addressed during the design and construction phases and a maintenance plan is implemented, both the scope and cost of future maintenance activities can be sharply reduced. Regional BMPs can offer significant economies of scale in terms of both capital investment and maintenance.

Pollutant Removal Benefits

(Depending on site-specific conditions)

BMP	*Suspended Sediments*	*Phosphorous*	*Nitrogen*	*Trace Metals*	*Organic Matter*	*Hydrocarbons*
grassed swale	0-40%	0-20%	0-20%	0-20%	0-20%	0-20%
wet pond	50-100%	40-80%	20-50%	30-50%	20-40%	60-70%
ext. detention dry basin	50-100%	40-50%	40%	50-90%	30-50%	60-70%
vegetated buffer	0-40%	0-20%	20-99%	0-99%	0-20%	0-20%
infiltration basin	75-90%	50-75%	45-70%	75-99%	70-90%	60-80%

Source: Schueler, 1987

The Land Management Project assists towns in water quality -related issues. For more information on this and other topics, contact the Land Management Project at 83 Park St., Providence, RI 02903, or telephone (401) 277-3434.

For more information on specific BMPs, consult the Land Management Project's Best Management Practices Fact Sheet Series.

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THE LAND
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Grassed Swales

BMP Fact Sheet No. 2 • September 1990

Grassed Swale: A Definition

A grassed swale is a constructed channel lined with grass or erosion-resistant plant cover used to convey runoff. Because runoff is slowed by vegetation as it travels through the swale, settling of sediments and uptake of pollutants by plants may occur. Swales are best suited for use in rural single-family residential areas and in highway median strips as alternatives to curb and gutter drainage systems. Because swales have a limited capacity to accept stormwater runoff from large areas they are most often used in combination with other BMPs (Best Management Practices) such as detention and retention basins, infiltration (percolation) devices, and created wetlands. Swales can be used in combination with other BMPs to improve performance and to add aesthetic value.

Key Findings

- **The use of swales is more economical than the curb and gutter systems they replace.**
- **The use of check dams within a swale can increase the amount of time that runoff remains within the swale, thereby enhancing runoff infiltration and uptake of pollutants by plants.**
- **Swales should not be used in areas that receive high volume, high velocity runoff. They should be used in combination with other BMPs.**
- **A layer of organic material placed along the swale's substrate will "boost" pollutant removal capacity.**
- **Swales require regular maintenance in the form of mowing, debris removal, and erosion prevention measures.**

How swales control runoff

First, a swale reduces the speed at which runoff is flowing, allowing BMPs receiving runoff from the swale time to effect treatment. Traditional asphalt-lined channels and drains accelerate flow and enhance erosion capacity.

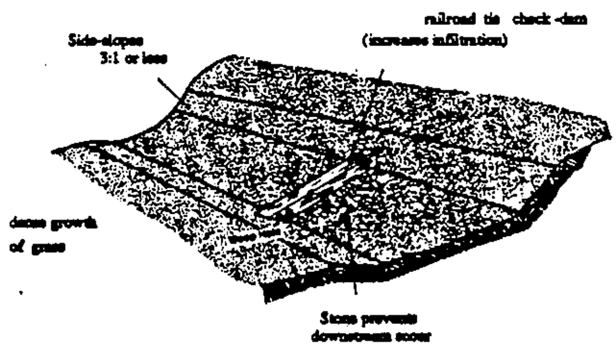
Second, a portion of the stormwater runoff passing through the swale infiltrates into the soil, and some waterborne pollutants are taken up by plants. The volume of runoff that infiltrates is limited by soil type and slope. Additional limitations include (a) the short amount of time that runoff is held in the swale in contact with soil and vegetation (the use of check dams will extend this time), (b) rapid soil saturation, and (c) the fact that swales adjacent to highways and roads are often heavily compacted in order to achieve a desired slope and load bearing strength. Infiltration rates in a swale will usually be near the minimum rates for the local soil types.

Swales and Pollution

Swales remove pollutants from runoff in three ways:

- By the **filtering action of vegetation** (plants can take up nutrients such as nitrogen and phosphorus which cause algal growth in lakes, freshwater ponds, coastal ponds and estuaries)
- By slowing runoff flow, some runoff-borne **sediment and associated contaminants are deposited** in the swale
- By **infiltration into the subsoil.** Results of scientific testing in Florida, New Hampshire, and Washington, D.C. indicated that, depending on soil type, flow rate, and other factors, moderate removal of particulate pollutants can probably be expected during small storms, if a swale is properly designed and maintained.

Typical Grassed Swale (cross-section).



Source: Schueler, T.R., 1987, Controlling Urban Runoff: a Practical Manual for Planning and Designing Urban BMPs, Metropolitan Wash. Council of Gov'ts.

Site Suitability

A limiting factor in the use of vegetative swales is the volume of stormwater runoff received. Areas that experience runoff velocities greater than four to five cubic feet per second are not suited to the use of swales. Other limiting factors are slopes (not to exceed 5% where a swale is to be constructed), and distance from groundwater (should be greater than two feet).

Swales are not designed to handle peak runoff loads independently. It is the use of swales in combination with other BMPs that are designed to provide more control that makes them important tools in runoff control and pollution reduction. These devices can be linked in a "treatment train" that provides more effective treatment than individual structures could provide. An example of such a train would be a swale leading into an extended detention pond that empties into a created wetland. The swale captures sand, silt, and debris which could clog the basin. Finally, runoff is then partially treated in the basin before entering the created wetland for complete treatment.

COSTS

A strong advantage to grassed swales is that they are more economical than the curb and gutter systems they replace. Once a selected site has been excavated and graded, a vegetative cover is easily established.

Average Costs for Swale Establishment:
(for a 15 foot wide, 3:1 sideslope swale, costs include excavating and grading)

Seeding/straw mulch:	$4.50 per linear foot
Seeding/net anchor:	$8.25 per linear foot
Sodding/stapling:	$7.75 per linear foot

Maintenance

The grass cover in a swale must be kept dense and healthy and should be of a hardy, low-maintenance type, such as red fescue (for a listing of suitable stormwater maintenance plantings see the *Rhode Island Soil Erosion and Sediment Control Handbook* (RI Dept. of Environmental Mgt., USDA Soil Conservation Service, RI State Conservation Committee, 1989). Maintenance involves mowing, occasional spot reseeding, and the removal of invading trees. The establishment of low native shrubs can enhance habitat value but the resulting loss of storage capacity within the swale must be accounted for in the design. Watering is necessary when establishing a swale and may be necessary in times of drought. Private homeowners are usually responsible for residential swale maintenance. Care must be taken to ensure that homeowners allow swale grass to maintain a height of at least a few inches, and that they minimize the use of fertilizers and pesticides, and that they keep swales clear of debris and trash.

Environmental value

Because residential swales are essentially extensions of home lawns, they have little wildlife or ecological value. However, roadside or backyard swales can be managed as natural areas with shrubs, wetland plants, and other additions that enhance landscape and habitat value. Nevertheless, mowing, trimming of vegetation, and maintenance are required to prevent nuisance mosquito breeding, exten- sive weed development, and erosion.

Design Guidelines

- To increase the time that runoff remains in the swale, use **check dams** (constructed of earth fill) from 6 to 24 inches in height to create small infiltration pools. These pools encourage biological uptake of pollutants. Make sure, however, that these pools hold water for no longer than 24 hours.

- Use grassed swales in areas that receive less than 5 cubic feet per second of runoff and have soil infiltration rates greater than 0.27 in./hr.

- A **minimum depth** of 2 feet to seasonal high groundwater is recommended to prevent potential contamination of nearby water supply wells. In addition, a **100 foot horizontal separation** between swales and private wells is recommended.

- Use a **minimum top width of 10 feet** and a **minimum swale length of 100 feet.** These are average values that will likely result in sufficient contact time and flow dispersion to provide pollutant removal.

- Parabolically-shaped (or bowl-shaped) swales move runoff in the least erosive manner and are the preferred design for swales. Maintain a **side-slope ratio of 3:1** to prevent erosion and for ease of maintenance.

- The use of warm season grasses, such as switch grass, and of low, brushy material, such as Korean Lepezeda, is recommended for vegetated swales as a way to further reduce runoff velocities.

- In general, design the swale to accommodate the expected runoff from a 25 year, 24 hour storm (an intense storm which has a probability of happening once every 25 years and would occur over a 24 hour period) if it is to be used in conjunction with other BMPs. Swale design can be more flexible and site-specific for small sites where flood control is not a concern.

- Introduce **organic material** into the soil surface. This will enhance swale ability to retain pollutants in the soil profile.

Source: Rhode Island Dept. of Environmental Management. 1988. *The Recommendations of the Stormwater Management and Erosion Control Committee Regarding the Development and Implementation of Technical Guidelines for Stormwater Management* .

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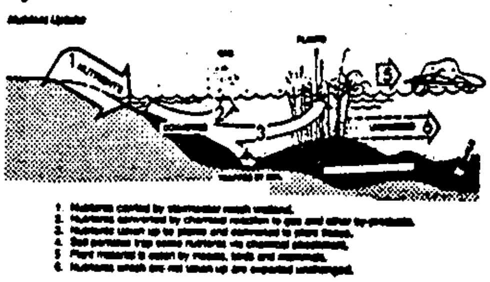
Artificial Wetlands

THE LAND MANAGEMENT PROJECT

BMP Fact Sheet No. 3 • September 1990

Created wetlands offer a unique stormwater control and pollutant removal system that is cost-effective to establish, operate and maintain. Wetland soils and vegetation serve to prevent or delay pollutant influx to receiving waters. Because of their ecological importance, the RIDEM Freshwater Wetlands Section prohibits use of natural wetlands to treat polluted runoff; however, *artificial* wetlands provide a means of managing nonpoint source pollution that is economically, socially, and practically viable. Artificial wetlands can be designed to optimize the treatment capabilities of natural ecosystems and to minimize their limitations. Often constructed as several "cells" in series, these systems offer important design advantages as BMPs: site selection, flexibility in sizing, and control over pretreatment, hydraulic pathways and retention time.



Key Findings:

- A wetland rarely functions as a permanent "sink" for nutrients and other contaminants; rather, it improves water quality by transforming, removing, storing, and releasing stormwater constituents at modified rates and times.

- Common runoff-borne pollutants which have been shown to be effectively treated by wetlands include BOD, nutrients, heavy metals, suspended solids, and hydrocarbons.

- In most wetlands, pollutant removal is seasonal, with a 30-60% removal of nutrients and dissolved substances during the growing season. A net export of nutrients and dissolved substances may occur during the winter when plants have died back and are decaying, or in early spring thaw conditions.

- Pollutant removal efficiencies will vary from site to site depending on climate, precipitation, vegetation, soil type, and watershed and stormwater characteristics. Proper hydraulic function is essential to success.

Construction

The design and construction of an artificial wetland must be based on a careful analysis of many complex relationships and characteristics within the watershed and on-site. These include: velocity and magnitude of flow, water depth and fluctuation, detention time, circulation, seasonal and climatic influences, groundwater conditions, and soil permeability (Livingston, 1989). The pollutant removal potential of mineral soils is generally boosted with an 18 to 24" organic soil layer, which takes up pollutants and supports plant life. Organic muck serves as a good seed source for establishment of vegetation but may be difficult to obtain and work with.

Seed sources should be free of *Phragmites* (common reed grass), an aggressive "invader species" having little wildlife value. Cattails are also extremely aggressive and may or may not be appropriate, depending on site-specific circumstances. In general, a minimum of five wetlands species are recommended to take advantage of the wetland's mixes in soil types, water circulation, and depth, which create habitat variations. A mix of species also increases the potential for vegetation to be present through the growing season, thus enhancing nutrient uptake. Consult a qualified landscape architect, nurseryman, or cooperative extension agent to select the plants best suited to the treatment system applications. System structure, hydrology and maintenance must also be site-specific to attain maximum efficiency.

Pretreatment

Pretreatment ponds and swales are designed to reduce stormwater volumes, sediments, oil and grease, and heavy metals entering the wetland system and will aid in maintenance by reducing scour and erosion. An example of an effective "treatment train" is a swale transporting runoff to a wet pond adjacent to the treatment wetland. Creating artificial wetlands, either in storm drainage retrofitting or in concert with other stormwater control systems, introduces the beneficial properties of wetlands to an area.

Maintenance

Over time, the soils and vegetation of the wetland may reach a saturation point, limiting their ability to adsorb phosphorus and heavy metals. Harvesting the vegetation and excavating the soils may extend the life of the system. A harvesting and replanting schedule for vegetation and an excavation and disposal plan for enriched materials should be developed prior to construction. An adjustable outlet structure which can occasionally be modified to raise the elevation of the permanent pool, thereby extending the system's life, is recommended.

Summary of Pollutant Removal Properties

Physical, chemical and biological processes all act to remove pollutants in stormwater. Adsorption, evaporation and precipitation are processes which can remove pollutants even during winter months.

Volatilization

Stormwater-borne oils, chlorinated hydrocarbons and mercury are removed via evaporation.

Sedimentation

Sedimentation (the physical settling of particles and attached pollutants) is important in removing suspended solids, particulate nitrogen and heavy metals. The rate of sedimentation depends on the size of the particle, hydrology, flow velocity, and storm size. Retaining stormwater in the wetland for several days promotes sedimentation and allows fine particles to settle out.

Adsorption

This is a chemical process in which dissolved pollutants (ammonium ions, phosphate and heavy metals) adhere to suspended solids, bottom sediments, or vegetation, and are removed from the water column. The process of adsorption is enhanced by shallow water depths and long residence times which increase the opportunity for contact between particles and dissolved pollutants

Precipitation

Slow flow velocities and lengthened detention/retention times also promote precipitation. In this chemical process, dissolved pollutants (heavy metals in particular) react with other elements in the water, forming an insoluble substance which sinks to the bottom and becomes incorporated with the sediments.

Filtration

As water moves through sediments and vegetation, particulate pollutants are filtered out. Sheet flow, reduced flow velocities and dense vegetation enhance pollutant removal. Filtration is effective in removing organic matter, phosphorus, bacteria, and suspended material.

Design Advantages of Artificial Wetlands for Stormwater Management

- can be used on regional and site-specific scales
- provide a "screen" between residential and industrial developments in urban areas
- self-regulating, cost-effective BMP option
- produces and supports a variety of wildlife
- aesthetically pleasing open space
- natural outdoor classroom/laboratory for students
- low area requirements
- good removal of suspended solids and nitrogen
- high phosphorus removal if water infiltrates soil and aeration is increased
- can be adjusted to seasonal variations in wetland hydrology

Benefits of Wetland Vegetation

- decreases shore erosion by soil stabilization
- mitigates force of wave action
- takes up nutrients
- traps large sediment particles
- maintains soil permeability
- adsorption of inorganic materials
- lowers water temperatures
- supply of oxygen to water column

Criteria for Plant Selection

- adapted to local environment
- tolerant of variable conditions (e.g. wave action, water levels)
- mix of easy seeders and perennials (strictly avoid "nuisance" plant seeds)
- commercial availability
- low maintenance; fast growing
- mix of submerged aquatic and emergent vegetation
- aesthetically pleasing
- erosion-control ability
- food source for wildlife

New Technology

Because of scientific uncertainty regarding long-term use of wetlands in stormwater management, design must be site-specific, maintenance must be regular, and use in a BMP "treatment train" is suggested. Seven treatment system designs are discussed in the handbook *Artificial Wetlands for Stormwater Treatment: Processes and Designs* (RIDEM Nonpoint Source Management Program, 1989). Consult the LMP to learn where other artificial wetlands can be viewed at LMP Demonstration Sites in Rhode Island.

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THE LAND
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Vegetated Buffer Strips

BMP Fact Sheet No. 4 • September 1990

The Problem

Urban watershed development often involves disturbing natural vegetated buffers for the installation of septic systems, construction of homes, parking lots and lawns. Vegetated Buffer Strips (VBS) perform several pollutant attenuation functions, mitigating the impact of development. When natural vegetation is removed, pollutants are given a direct path to water resources - - sediments can't settle out; nutrients and other pollutants can't be attenuated. Additional problems resulting from removal of natural vegetation include thermal pollution, streambank erosion and loss of valuable wildlife habitat.

The State of Rhode Island's Freshwater Wetland Act requires setbacks of the following widths: 50' from any wetland; 100' from any stream less than 10' in width; and 200' when a stream exceeds 10' in width. With respect to coastal resources, CRMC requires buffers that preserve and where possible restore ecological systems. Both agencies regulate alterations within these areas "case-by-case," taking into account the nature of the disturbance, relationship with surrounding land uses, and site-specific conditions.

Key Findings

• Buffers can help restore and maintain the chemical, physical, and biological integrity of water resources by attenuating runoff-borne pollutants, encouraging infiltration, reducing sedimentation, stabilizing streambanks, and preserving natural ecosystems.

• Forested buffers can take up nutrients from shallow groundwater, shade streams, reduce thermal pollution (encouraging trout and other desirable aquatic species), and provide a stream corridor habitat for wildlife.

• VBSs mitigate the impact of flooding by increasing flood storage capacity and reducing the velocity of storm surges -- thereby minimizing public investment in waterway restoration, stormwater management, and structural flood control measures.

• The best site conditions for buffers have shallow slope, soils that have high levels of microbial activity (for forested buffers), and very poorly drained soils (for buffers serving wetland functions).

Role of VBSs

A vegetated buffer strip (VBS) can be either naturally occurring or "engineered". Engineered VBSs have been used to manage agricultural runoff for some time. Natural buffers have been defined as undisturbed areas located between areas of human activity and water or wetland resources. Vegetated buffer strips slow the flow of overland runoff. Where slow sheet flow can be encouraged, buffers promote infiltration to groundwater, accommodate vegetative uptake of pollutants, and maintain the temperature of runoff entering the receiving water. Depending upon soil type, pollutants most effectively taken up include nitrates and heavy metals. Buffers strips offer much more than just water quality benefits -- they provide excellent wildlife habitat and aesthetic value. VBSs can also be integral to greenways, serving flood hazard management and recreational purposes.

Components of a Buffer

The primary physical components of a VBS include: soil, vegetation, depth to groundwater, and slope. Each component must be considered when evaluating the pollutant attenuation value of a VBS. To minimize installation and maintenance costs, preservation of native materials is encouraged. CRMC requires that developers minimize the disturbance of buffer areas adjacent to coastal resources. It is of the utmost importance to avoid channelization, and to ensure that flow of runoff through the buffer is "sheet flow." Flow through existing natural buffer areas can be pretreated in grassed buffers or swales.

Soil Type

The slope, hydrologic class, chemical and physical properties, and pH of the soil should be considered when evaluating installation and/or use of existing buffer areas.

The slope is related directly to the erosive capability of the soil type. On steep slopes where highly erodible soils occur, overland flow through buffers may be inappropriate, or a "stepped" conveyance for runoff may be required. The hydrologic class, representing the runoff producing capability of the soil, is important to know in order to evaluate infiltration capacity. Soils in SCS Classes A & B have good infiltration rates and are preferred in forested buffers. Soils having high microbial activity can enhance the level of denitrification, reducing the load of nitrates available to runoff. Chemical properties of the soil are also important in determining which pollutants are adsorbed by the soil.

Groundwater

Buffer strips also have proven fairly successful in attenuating some pollutants transported in shallow groundwater. The primary factors are the drainage class of the soil and its pH level. Recent research has shown the importance of pH in the ability of a vegetated buffer strip to attenuate pollutants carried in groundwater. More acidic soils attenuate larger amounts of nitrates and phosphates while basic soils slow the movement of heavy metals. In buffers that contain poorly or very poorly drained soils, almost complete nitrate removal can be achieved from groundwater flow when the groundwater is within 23 inches of the surface (Groffman, 1990).

Vegetation

The types of vegetation incorporated into a buffer zone will determine the level of maintenance and pollutant removal efficiency possible. During the growing season grasses from the fescue family can attenuate close to 99% of nitrate in groundwater flow. Native shrubs and trees, whose root zones are of sufficient depth to provide vegetative uptake of certain pollutants, should be used in conjunction with grasses. The vegetation used in an engineered VBS should require little to no maintenance, except for the occasional clearing of dead vegetation.

Wildlife Habitat

Vegetated buffers are important to wildlife species diversity, particularly when linked in contiguous fashion. They provide space for movement, sites for breeding and foraging, refuge from flooding, and shelter from adjacent land uses. When creating or evaluating a buffer for wildlife value, key factors include: habitat suitability, space requirements of the predominant species, access to upland, and noise impacts. In Rhode Island, rare species such as the smokey shrew have been sighted in buffers. Other animals such as shrews, voles, frogs, turtles, rabbits, opossums, salamanders and over forty-four varieties of birds also live in Rhode Island buffers (Husband, 1990).

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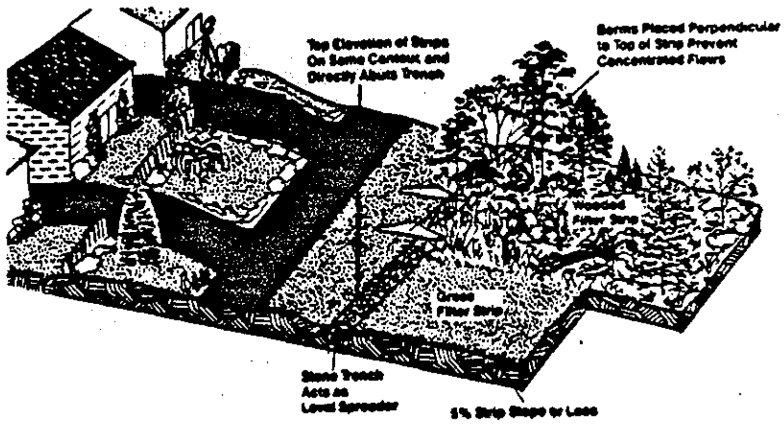
Sizing

From both a scientific and political standpoint, the sizing of vegetated buffer strips is a contested parameter. Suggested widths range from 25' to 300' and greater, depending on site-specific characteristics. The absolute minimum required to attenuate some forms of groundwater pollution is 25' (Groffman, 1990). In Maryland a 75' buffer is required in most cases to partially mitigate the impacts of polluted runoff that could potentially reach water resources. The State of Maryland also applies a 300' standard when adjacent slopes exceed 15%. When the area to be disturbed is determined to be a significant wildlife habitat, a buffer of at least 300' is suggested (Husband, 1990). Site-specific characteristics and limitations should be considered to determine the buffer dimensions required to address specific objectives.

Vegetated Buffer Strip Diagram



Source: Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing BMPs.* Metropolitan Washington Council of Governments.

Cost Effectiveness

Vegetated buffer strips are a low cost and easy technology to implement to help mitigate the negative impacts of nonpoint source pollution. Many states require the use of vegetated buffers in development adjacent to a water resource (a summary of various requirements is available from the LMP). Scientists at URI are currently investigating the characteristics of buffers which contribute to uptake of specific pollutants from both overland sheet flow and groundwater flow.

References:

Narragansett Bay Project. 1990. *Vegetated Buffer Strip Designation Method Guidance Manual.* NBP, Providence, RI.

Groffman, Husband, et al. *An Investigation into Multiple Uses of Vegetated Buffer Strips.* Narragansett Bay Project (in press).

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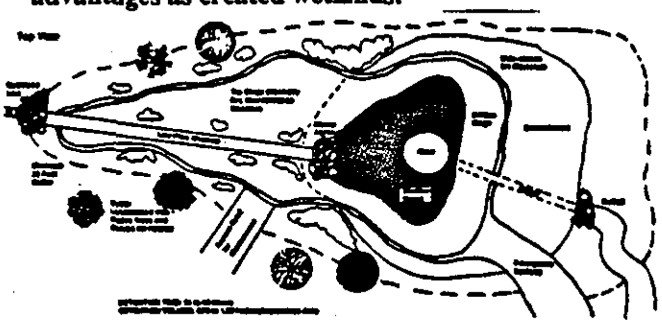
THE LAND MANAGEMENT PROJECT

Extended Detention Basins

BMP Fact Sheet No. 5 • September 1990

Extended detention basins are the least cost urban BMP that can both remove pollutants and control flooding. Extended detention dry basins meter out collected runoff at significantly slower rates than dry flood control basins, allowing for enhanced physical settling of sediments and greater biological uptake of pollutants. Extended detention wet basins incorporate stormwater control, extended detention, a permanent pool, and a shallow fringe marsh environment. The latter basins are capable of double the rate of dissolved nutrient removal achieved by dry basins. Physical, chemical, and biological treatment processes are involved.

Extended detention systems are effective in keeping the peak discharge rate (the maximum speed at which runoff is flowing) at a level equal to that which occurred prior to development (Schueler, 1987). Proper design of the basin is dependent upon the volume to be detained and the duration over which that volume is to be released to both treat pollutants and manage flood flows. Dry extended detention basins drain completely between storm events and can be mowed, whereas wet extended detention basins offer some of the same advantages as created wetlands.



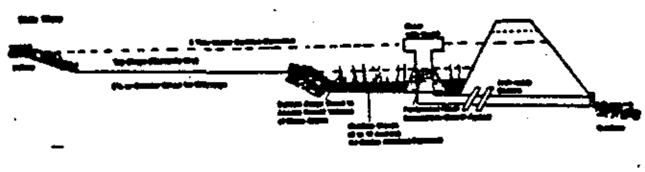
Key Findings

• Extended detention basins designed for 24-hour minimum detention times have been found to effectively remove more then 2/3 of sediments, total nitrogen, phosphate and trace metals contained in runoff (Harrington, 1986). Wet extended detention basins can achieve even higher removal efficiencies if properly designed and maintained.

•Extended detention basins are most effective in achieving flood protection in the central and upper central portions of a watershed and are best suited to serve areas greater than 30 acres (Schueler and Helfrich, 1988).

• By changing the outlet elevation and increasing the storage volume, existing dry ponds can be easily and cost-effectively retrofitted (10-15% additional construction costs) to achieve the effects of extended detention.

• Settling is the primary mode of pollutant removal in extended detention ponds, together with the biological removal of soluble pollutants by marsh plants, algae and sediment-dwelling organisms.



source: Schueler, 1987

Siting and Design Considerations

Recommended design criteria for extended detention basins are included in the Stormwater and Erosion Control Committee's *Recommendations Regarding the Development and Implementation of Technical Guidelines for Stormwater Management* (1988). These suggest the detention of runoff volumes generated from the 1-year, 24 hour storm event for a minimum of 24 hours (approximately 2.7" of rainfall), the designated "water quality control" design storm.

Extended detention basins are most effective in achieving *flood protection* regionally in the central and upper central portions of a watershed, but can be used in combination with on-site peak shaving devices. Extended detention *wet* basins are most appropriate where discharge of nutrients (dissolved phosphorus and nitrogen) to receiving waters can cause eutrophication or loss of use - e.g. watersheds of reservoirs or lakes. Wet basins provide more attractive amenities than dry basins (e.g. wetland conditions) but have greater storage requirements and require more land.

Recommended minimum standards for water quality and flood control

- *Sensitive Areas* - In the watersheds of water supply reservoirs and coastal ponds, the design should provide for sediment settling that removes 85% of sediment and associated contaminants.
- *Non-sensitive Areas* - The design should provide for a solids removal efficiency of 70%.

Source: RI Stormwater and Erosion Committee, 1988

Estimated Pollutant Removal by Extended Detention Dry Ponds

Sediment
60-70% in the first 6 hours
80-90% in approximately 48 hours

Phosphorous
40-50% in approximately 48 hours

Nitrogen (particulate)
25-50% in approximately 48 hours

Organic Matter
40-50% in 32-48 hours

Trace Metals
40-90% in approximately 48 hours

Source: Chesapeake Bay Program, 1987

Maintenance

Maintenance requirements are similar to those of conventional dry ponds, although the longer detention times may create sustained marshy conditions which impede mowing and debris removal. Each design should also include provisions to prevent clogging of small orifices, and provide adequate storage for sediments in order to avoid frequent sediment dredging (wet basins require less frequent clean-outs). However, sediments must eventually be removed mechanically and a plan for disposal of sediment should be established at the time of construction.

Maintenance Concerns:
- moderate to high routine maintenance requirements
- trash accumulation
- wet conditions through the growing season may induce marsh growth, impeding mowing and debris removal
- access to the basin must be provided for ease of maintenance

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Advantages of Extended Detention BMPs

- Improved stormwater quality plus the retention of a greater peak flow than that provided by conventional dry ponds (randomly placed dry ponds can actually cause flooding throughout the watershed)
- No discharge of untreated first flush -- the first portion of stormwater discharge, carrying a disproportionately high pollutant load, is detained
- Greater removal of pollutants than that obtained with conventional dry ponds
- Creation of local wetland and wildlife habitat
- Dry out within a short period, providing for ease of maintenance and eliminating potential mosquito breeding

Limitations

- Limited protection of downstream aquatic habitat
- Occasional aesthetic problems in the lower portion of the pond
- Moderate to high routine maintenance requirements and eventual need for costly sediment removal
- If appropriate measures are not taken to prevent resuspension of sediments, runoff may cause scouring and discharge of previously settled sediments

Cost Effectiveness

Costs of extended detention systems can vary substantially on a site-specific basis. However, storage volume and cost are closely related for any type of detention pond; cut-fill expenses account for about 50% of the total cost and the inlet-outlet structure for 33% (Schueler, 1987). Annual operation and maintenance costs are estimated at 3-5% of base construction costs. Extended detention dry ponds cost approximately 7-10% more than conventional dry ponds and achieve roughly double the removal of some pollutants.

Conventional dry basins can be converted to extended detention basins for additional construction costs of approximately 10-15% (storage volumes are generally increased 15-25%). Additionally, extended detention dry ponds cost approximately 16-50% less than conventional wet detention basins. Although wet extended detention basins require greater capital outlay, they offer much greater treatment efficiencies and other amenities such as wetland habitat and reduced maintenance cost.

Recommended sources for additional information on costs, siting and design considerations include: *Recommendations Regarding the Development and Implementation of Technical Guidelines for Stormwater Management* (RI Stormwater Management and Erosion Control Committee, 1988), *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's*, and the LMP's *Stormwater Basin Plants and Landscaping Guide* (1990). Further, five design variations for extended detention wet basins are profiled in *Design of Extended Detention Wet Pond Systems* (Schueler and Helfrich, 1988).

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THE LAND MANAGEMENT PROJECT

Infiltration Devices

BMP Fact Sheet No. 6 • August 1990

Infiltration Devices : A Definition

Infiltration devices are structures designed to intercept stormwater runoff in order to reduce the overall amount of runoff discharged from a site and to remove water-borne pollutants by filtering them through the surrounding soil.

This design is best suited for use in small watersheds that do not have concentrated, erosive flows and heavy sediment loads. Infiltration devices, when used with pretreatment devices such as grassed swales and sediment traps, are very effective in treating the "first flush" of runoff (usually defined as the first 1/2 inch of runoff) which contains the bulk of pollutants and sediments being transported. The ability of an infiltration device to effectively remove pollutants is highly dependent upon the underlying soil conditions and is also affected by temperature and rainfall intensity.

Key findings

- Studies conducted in the Washington, D.C. area show that infiltration devices are particularly effective at removing sediments, trace metals, bacteria, and BOD (biochemical oxygen demand) from stormwater runoff.
- These devices provide an important groundwater recharge function and can reduce runoff volumes to the pre-development level.
- The primary reason for infiltration device failure is clogging with sediment. This can be prevented by the use of pretreatment devices (e.g. swales, grit traps, catch basins).
- Maintenance requirements for infiltration BMPs are extensive and their use should only be considered if consistent maintenance can be guaranteed.
- Infiltration devices are the most effective BMPs for protection of downstream aquatic life.

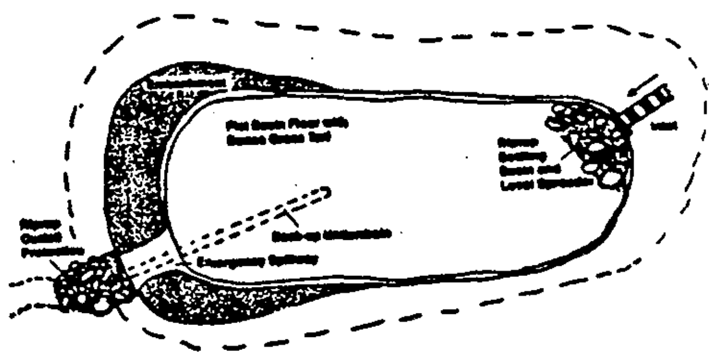
How Infiltration Devices Control Runoff

When a watershed area is developed, land that was once covered with plant life (which absorbs stormwater) is replaced by pavement and impervious surfaces that do not allow rainwater to infiltrate into the soil. This greatly increases runoff volume and velocity. Infiltration devices can catch and hold runoff, allowing it to infiltrate into the soil.

Infiltration devices divert a significant portion of annual runoff volume back into the soil. This groundwater recharge function helps maintain flow levels in small to medium-sized streams during periods of drought thus protecting aquatic habitat areas. Unless groundwater is sufficiently recharged, streams in developed areas suffer drastically reduced flows in the summer months.

Infiltration devices help dampen flooding effects on downstream areas by reducing the frequency and size of flood flows. This reduction of flow helps prevent streambank erosion and provides flood control.

Infiltration Basin



Source: Schueler, T.R., 1987, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Wash. Council of Gov'ts.

Infiltration Devices and Pollution

Although the pollutant removal capability of infiltration devices has not been tested extensively in the field, findings derived from recent testing and from wastewater disposal practices indicate that soil is a highly effective and normally safe filter for pollutant removal.

Removal rates depend upon the chemical characteristics of individual pollutants, length of storage time, and soil type. Pollutant removal effectiveness can be "boosted" by putting a layer of organic material beneath the floor of the device.

Device Types

- **Infiltration basin** - a large, flat-bottomed basin which holds and infiltrates a certain amount of runoff into the grass-covered basin floor. These basins are designed for pollutant removal and for floodwater control.
- **Recharge basin** - similar to an infiltration basin but designed for groundwater recharge only.

- **Infiltration trench** - a 3'-8' deep trench, backfilled with stone to form an underground reservoir. Runoff filters into the soil and excess storm flow can be routed to an outflow facility. The trench is lined with filter fabrics to trap sediment. Grass buffers are recommended to catch larger particles. These trenches, like other infiltration devices, should be used in combination with pretreatment devices to prevent clogging.
- **Off-line basins and trenches** - These designs shunt "first flush" runoff out of a channel, separate sediments, and allow the remaining runoff to infiltrate into the soil.
- **Dry well** - a trench variation designed to accept rooftop runoff from residential and commercial buildings. These smaller devices infiltrate all runoff.

Site Suitability

Soil type is a primary constraint to the siting of infiltration devices. Soils belonging to the USDA Soil Conservation Service's Class "D" category (infiltration rates less than 0.27 in/hr.), or any soil with clay content greater than 30% are not acceptable for these devices. Class "C" soils provide marginal infiltration rates and should generally not be considered suitable. Devices located on fill soils are unstable and prone to slope failure.

Soils best suited are sandy, or loamy, or a mixture of these two types (mostly Class "A" types). These soils allow infiltration and provide good pollutant removal capabilities. ***Core samples should be taken over the entire device area because soil conditions can vary substantially over short distances.*** Soil information from the *Soil Survey of Rhode Island*, (USDA Soil Conservation Service, 1981) can be used for a preliminary site evaluation but site-specific evaluation should be done in order to avoid unsuitable areas.

Costs

Because so few infiltration devices have been constructed, there is insufficient information to make general cost projections. However, infiltration basins are similar in design and construction methods to dry ponds, so figures approximately 10 to 20% more than dry pond cost projections can be used. One cost advantage to basin-type BMPs is that they can serve as temporary sediment basins during the construction phase of development, thereby fulfilling erosion control requirements. All sediment must, however, be thoroughly removed from the device at the end of the construction phase in order to avoid early failure by clogging. Infiltration trenches are the most economical BMP for small sites because their small size requires less excavating and grading.

Environmental value

Infiltration devices maintain pre-development water balances, filter out pollutants, help ensure adequate stream flow during summer months, and do not exhibit the thermal impacts associated with other BMPs.

The value of infiltration basins as wildlife habitat is minimal - they do not provide food or shelter. However tree and shrub plantings around the basin perimeter can enhance habitat value.

Studies performed on Long Island, NY, by the U.S. Geological Survey (1986) have indicated that infiltration basins achieve near complete removal of chemical and bacterial components of stormwater. However, the studies showed little or no removal of chloride (from road salt) and nitrogen (from fertilizers and septic systems). This can be controlled to a degree: vegetative material on or under the basin floor is used to take up nutrients (although still no chloride removal capability). Design and siting of these devices should adhere to the guidelines set forth in *The Recommendations of The Stormwater Management and Erosion Control Committee Regarding The Development and Implementation of Technical Guidelines for Stormwater Management*, RI Dept. of Environmental Management, 1988.

Maintenance

These devices have **extensive maintenance requirements** and their use should only be considered if consistent maintenance can be **guaranteed.** Lack of proper maintenance can turn an infiltration device into a community eyesore or a mosquito breeding site. The use of pretreatment devices will extend the effective life of an infiltration device. According to a survey in Maryland, annual maintenance costs are estimated to be 3-5% of construction costs, based on limited data. This should be considered an interim estimate until more device maintenance experience has been gained.

General Maintenance Practices include:

- Periodic tilling of basin floors
- Revegetation of basin floors and buffer strips
- Reseeding of eroded or barren areas
- Periodic mowing of turf in basins and buffer strips
- Sediment removal in buffer areas
- Routine inspections on a regular basis

Problems in Design

To date, infiltration devices have had fairly high rates of failure. It appears that this is preventable to a degree. From experiences in Maryland, where many of these devices are in operation, it is reported that performance problems are attributable to **(a)** *poor design and location* (over poor soils, in areas of high sedimentation), **(b)** *poor construction techniques*, **(c)** *inadequate pretreatment* to prevent clogging by sediment, **(d)** *inadequate maintenance practices.*

Overall, infiltration devices can be effective parts of comprehensive stormwater management plans if care is taken in the design, construction, and maintenance of these structures.

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THE LAND
MANAGEMENT
PROJECT

Alternative Turf

BMP Fact Sheet No. 7 • September 1990

The Problem

A few hours of proper planning can avoid thousands of hours and dollars spent on future lawn maintenance. Lack of planning before planting can result in a lawn that is of low quality, and requires intensive watering, fertilizing, mowing, and pesticide use. Paying close attention to the characteristics of the site -- orientation, shading, soil pH, permeability, and moisture content -- is essential if a lawn is desired that is "low-maintenance" and "low-input".

The future quality of the turf and the amount of care that it will require depends on the suitability of the grass types that are planted, the level of watering, and the fertilizing regime. Due to a recent increase in species and cultivars available for use as turf, the landscape manager and home owner now has the opportunity to choose turf that is "environmentally sound" and well suited to a specific homesite, golf course, or other large turf area.

Key Findings

• Turf grasses grow best and have less impact on water quality when slightly stressed. Roots grow longer and stronger, improving resistance to drought and wear.

• Mixing plantings of native vegetation with areas devoted to "low-maintenance" and "low-input" turf helps avert common water quality impacts associated with lawn care -- leaching of fertilizers and pesticides.

• Turf types are fairly site specific, but a number of types compatible with a given soil can often be blended to attain desired lawn characteristics.

• Growing demand for the construction of golf courses has made surface and groundwater vulnerable to fertilizer and pesticide pollution. In Maine and elsewhere in New England, alternative turf has been used on greens, fairways and other large grassed areas to lessen maintenance demands and mitigate water quality impacts.

Lawn Gardening

The good old, clean-cut American lawn is back in style. We love our lawns -- especially when they are neat and trim. Lawn care is the most popular gardening activity in the U.S., outpacing vegetable, flower, fruit, and houseplant gardening. In fact, more people tend lawns than read books, go to movies, or watch sports on TV. There are 5 million acres of home lawns in the United States, with close to 150 trillion grass plants under cultivation. Americans spend $6 billion a year to keep them looking good (Schultz, 1989).

In response to increasing concerns about the impact of lawn maintenance on water quality and quantity, scientists and breeders have been developing grasses that are resistant to insects, heat, cold, and drought. New grasses under development at URI stay green longer without fertilizer and grow quickly and thickly enough to crowd out weeds.

Some of the new varieties of grasses (such as, red, hard, and chewings fescues) thrive in shade and stand up to heavy foot traffic. These turfs minimize the amount of fertilizers, nutrients and pesticides available to collect in runoff and degrade water resources.

Alternative Turf

Fine Fescues

Grasses in the Fine Fescue family (red, hard, and chewings) are hardy, deep green, and require only half the water of blue and rye grasses. Further they are the most shade tolerant of the turf grasses. Fine Fescues also have a good wear resistance, making them suitable for play areas. Fine fescues may be less lush than traditional turfs, though, and may brown out more quickly for longer periods during drought. Of the three fine fescues generally available, hard fescues are the most reliable in terms of ease of maintenance.

Tall Fescues

With a history similar to ryegrass, Tall fescues are no longer viewed as "weeds" but as turf grasses. Drought tolerant Tall Fescue requires little to no fertilization, and is both heat and wear resistant. New varieties offer a rich green color, require little nitrogen input, and show resistance to such diseases as brown patch, leaf spot and stem rust. Tall fescue is well adapted to a range of soil conditions, including acid soils in the range of pH 5.5 to 6.5.

Perennial Ryegrass

Original varieties of this turf grass were used only for agriculture and not for lawns. In the 1960's new disease-resistant strains of the grass were developed that were instantly popular. In addition, endophytes were discovered on the grasses that made them bug-resistant. Perennial Ryegrasses have moderate heat tolerance and cover very quickly.

Traditional Turfs

Kentucky Bluegrass

This turf grass type is the most common lawn grass in the northeast. It can be planted alone or blended with other turf types. The strength of Kentucky Bluegrass is its lushness and its moderate tolerance to disease and drought. It stays green into the fall and greens up again in the spring before the other grasses. However Kentucky Bluegrass requires fertilizing and heavy watering - two inches a week during the growing season.

Bentgrass

The bentgrasses are fine textured sod-producing perennials. Familiar as the turf that putting greens are made of, they don't really belong in the home lawn. They are high maintenance, requiring constant watering, fertilizing, and mowing. The bentgrasses don't mix well with other low-maintenance grass types.

Characteristics of Turf Grasses Suitable for the New England Region

Turf Type	Texture	Nitrogen Requirements	Heat Tolerance	Cold Tolerance	Drought Tolerance	Wear Tolerance	Rate of Establishment
Traditional							
Kentucky Bluegrasses	Fine	Moderate	Low	High	Moderate	Moderate	Slow to Moderate
Bentgrasses	Fine	High	Low	High	Low	Low	Slow
Alternative							
Perennial Ryegrasses	Fine	Moderate	Low	High	Moderate	High	Fast
Fine Fescues	Fine	Low	Low	Moderate	Moderate	Moderate	Moderate
Tall Fescues	Coarse	Low	Moderate	Moderate	High	High	Moderate
Source:	Schultz, 1989		Low	High	Low	Low	Slow

Resources:

Cooperative Extension, University of Rhode Island, 792-2900.

URI Agricultural Experiment Station, 792-2475.

Warren Schultz. *1989. The Chemical -Free Lawn: The Newest Varities and Techniques to Grow Lush, Hardy Grass.* Rodale Press, Emmaus, PA.

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What Towns Can Do

- **Require the use of specific turf types in sensitive areas**
- **Limit the area of a site devoted to lawn**
- **Encourage "Mesi-scaping" (landscaping using species that require minimal fertilizer and water inputs)**
- **Incorporate alternative turfs in municipal projects**

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THE LAND MANAGEMENT PROJECT

Wet Retention/Detention Basins

BMP Fact Sheet No. 8 • September 1990

Retention

In retention facilities, stormwater is diverted, stored in a "permanent pool", and gradually removed via infiltration into the soil, evaporation, and/or plant evapotranspiration (rather than discharging to surface water). Pollutants are removed through sedimentation and through chemical and biological processes. Slow infiltration rates, combined with increased mean residence times in the wet area, favor retention of pollutants (especially metals) in the sediment (Yousef et al, 1986). Retention basins or off-line wet ponds have permanent pools and store stormwater for long periods of time (days to weeks).

Detention

Detention basins or on-line wet ponds provide temporary storage of excess runoff on the site prior to its gradual release after the peak of the storm inflow has passed. Stormwater is slowly released at a rate no greater than the pre-development peak discharge rate (hours to days). Detention will not generally reduce the total volume of runoff, but will redistribute the rate of runoff over time by providing temporary "live" storage. Detention provides flood control and treats the *"first flush"* of stormwater through chemical transformation and biological uptake between storm events. Detention times of greater than 3 days are recommended, with an optimal storage time of 14 days to enhance the treatment of soluble nutrients.

Key Findings:

•In Orlando, FL and Fairfax County, VA, parks and recreation facilities, institutional lands and public rights-of-way are being used to site dual-purpose, *regional stormwater storage and pollution control* facilities.

• Wet ponds are multi-purpose BMPs -- they provide *flood hazard management (peak-shaving), pollutant* removal, and landscaping/habitat improvement.

• Wet detention and retention basins can allow for physical settling of sediment-associated pollutants or can serve as "controlled eutrophication" sites where nutrients are processed.

• The degree of pollutant removal achieved is a function of the size of the basin in relation to the contributing watershed, design of the permanent pool and the characteristics of individual urban pollutants.

• Large regional or multi-site facilities provide more predictable water quality and quantity management are preferred (rather than small on-site facilities) and are more cost-effective in terms of construction and maintenance (Chesapeake Bay Program, 1987).

Cost Effectiveness

Wet basins are most cost-effective in larger, more intensely developed sites with a reliable source of water in order to maintain the permanent pool (greater than 20 acres). Because of their sizing requirements, these basins are also an effective regional stormwater management device and provide a watershed-oriented, comprehensive BMP that can be cost-effectively constructed and maintained by a municipality. Wet basins are recommended for watersheds of reservoirs and lakes where nutrient loading is of concern and the advantages of the basin's permanent pool can be maximized. Wet basins are generally larger than other BMPs and are 30-60% more expensive than dry ponds of similar stormwater capacity (Schueler, 1987).

Yet, these basins are more cost-effective with greater size. Wet ponds generally offer 30-200% extra storage and cost 20-100% more than a conventional 2-yr. storm dry pond (approximately $100-1,500 per acre served). Construction and maintenance costs for retention facilities are similar to those of detention basins for an equal volume. However, depending on the infiltration rate of the soil, it may be necessary to use a greater storage volume if no discharge to surface waters is sought (Chesapeake Bay Program, 1987). Because sediment and debris accumulate in the permanent pool, wet basins require less frequent cleanouts to prevent clogging than dry ponds and extended detention dry ponds. If sufficient sediment storage is provided for, routine maintenance is simple.

Pollutant Removal Efficiency

Removal efficiency for both retention and detention facilities is similar to that of extended detention dry ponds for particulate pollutants (approximately 11% for nitrogen and phosphorus), slightly lower for removal of organics, and higher for sediments and trace metals (75-99%). Efficiency for sediment removal is approximately 80-100%. Efficiency is dependent upon holding time, amount of shallow wetland available, location of inlet and outlet, and incorporation with other BMPs in series.

Studies in Florida concluded that 99% of the total phosphorus input accumulated in the sediments and 85-90% of the total nitrogen was removed by nitrification/denitrification in retention facilities. The studies also found no pollutant hazard to nearby surface or groundwater, and quantity control was frequently 100% (Chesapeake Bay Program, 1987). Retention basins also provide higher removal efficiencies of metals and nutrients than detention basins.

Pollutant Removal Mechanisms

Sedimentation, the physical settling of particles and attached pollutants, is the primary pollutant removal mechanism in both retention and detention facilities. Sedimentation is important in removing suspended solids, particulate nitrogen and heavy metals. The basin's permanent pool acts as a barrier to resuspension of deposited materials, improving removal performance over that of dry ponds. The greatest initial settling in detention basins occurs near the inlet structure.

Aquatic plant and algae remove soluble nutrients from the water column and convert the soluble nutrients to biomass which settles and is consumed by bacteria. Adsorption and biodegradation also occurs in retention facilities as stormwater percolates through the soil. Additionally, stormwater-borne oils, chlorinated hydrocarbons and mercury are removed via evaporation.

Design Considerations

In order to maximize the multi-purpose functions of wet ponds, pond geometry, depth, vegetation, soils, and microtopography must be carefully considered. The distance between the pond inlet and outlet should be maximized in order to prevent incoming runoff from passing through the pond without displacing the old water (dead storage). Pond depths should be variable, with a shallow shelf on the fringe and near the outlet structure for safety and establishment of wetland vegetation. For ponds exceeding one acre in size, average depths should range from 3 to 6 feet in order to provide productive fish habitat. At least 50% open water should be maintained for mosquito control. Low aquatic vegetation should be established in the perimeter (approximately 30% of the area) to provide wildlife habitat, prevent erosion, trap incoming sediment, and improve appearance. Gentle slopes reduce erosion and provide ease of maintenance. Structural or vegetative fences may also be provided for safety.

Detention ponds should be constructed in less permeable soils (B, C, and D hydrologic groups) or be constructed with a clay liner or filter fabric to minimize infiltration. Pretreatment with landscaped retention areas or perimeter swales can reduce the pollutant load of oil, grease, metals and sediment and may help prevent algal blooms.

Retention facilities are limited to sites with deep water tables and soils having slow percolation rates in order to enhance chemical, physical, and biological pollutant removal processes (e.g. bacterial activity). For more detailed design specifications for basins providing both flood and water quality protection, see the RI Stormwater and Erosion Control Committee's *Recommendations Regarding the Development and Implementation of Technical Guidelines for Stormwater Management* (1988).

Maintenance

Routine

- mowing (buffers)
- wet weather inspections
- debris and litter removal
- nuisance control (weeds, insects, odor, and algae)

Non-Routine

- structural repairs and replacement
- sediment removal (10 to 20 years)

Annual operation and maintenance costs are estimated at 3-5% of initial construction costs. Routine maintenance costs range from $300 - $500 per maintained acre (including the pond and buffer).

Advantages

- flow attenuation, flood and pollution control
- creation of local wildlife habitat
- recreation resource
- landscape amenities
- potentially higher property values (due to the above amenities)

Potential Disadvantages

- downstream habitat degradation (e.g. thermal impacts, dissolved oxygen depletion)
- potential safety hazards
- occasional nuisance problems (e.g. odor, algae, debris)
- sediment removal and restoration at 10-20 year intervals
- sites suitable for retention facilities must be carefully screened (designs should incorporate protection of groundwater quality, especially in sensitive areas)

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